Physico-Chemical Characteristics And Industrial Potentials Of Lepidolite From Ijero-Aramoko Pegmatite Field, Southwestern Nigeria.

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Abstract: Physico-chemical characteristics and industrial potentials of lepidolites from Ijero-Aramoko pegmatite fields were investigated . Systematic mapping indicates that the lepidolite is associated with steeply inclined pegmatite intruded into the basement rocks of gneisses and schistose assemblages that are in places pulsed with isolated Pan-African granite. The lepidolite has a layered structure, a perfect unidirectional cleavage and equigranular texture. Thirty lepidolite samples were collected from the pegmatite fields and anaylsed using the Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES) method .in the Activation Laboratories, Ontario Canada. The results of the analysis indicate that the silica (SiO_2) content in the lepidolite ranges between 49.43 and 50.16% in Oke-Asa, 49.49-50.43% in Oke-IgboAba and 57.87-57.81% in Ijero-Ekiti mineralized areas . Average Al_2O_3 contents in these three areas are 27.83%, 23.02% and 28.34% respectively. In the same trend, K_2O has the following average values 10.06%, 9.41%, and 5.86% while MgO, CaO and TiO_2 values are generally less than 0.3% in all the samples. Trace element composition reveals higher Li, Be, Cs and Rb contents relative to Ta, Nb and Sn. The average Li values of 1859 ppm, 1778 ppm, and 1656 ppm are recorded for Oke-Asa, Oke-Igbo Aba and Ijero Ekiti respectively. The high contents of SiO_2, Al_2O_3, and K_2O as well as the unusual amount of lithium and microcline reveal the general geochemical characteristics of the lepidolite on which its industrial applications are based. Lithium compounds form sources of raw materials in the pharmaceuticals and in the making of energy lithium batteries and serves as an alloy of aluminium, magnesium and zinc.The physical tests reveal high specific Gravity (2.69-2.80; ca. 2.74), compressive strength (45.84-50.14; ca. 48.93) N/mm^2, wet density (2.30 to 2.65; ca. 2.39) g/cm^3, and less water absorption capacity (0.21 to 0.35; ca.0.26) %, . These physical characteristics make the lepidolites suitable for use in various industrial areas where lithium compounds are employed.

Index Terms: Enriched-lithium, industrial potentials. Ijero-Aramoko Ore, pegmatite.

1.0 Introduction

lepidolite is a source of lithium and it is industrially useful in lithium storage batteries, ceramic wares, smelting of aluminum ores as well as reduction of shattering in glass. Lithium has the highest specific heat capacity (the largest of any solid) and as such, it is useful in heat transfer processes and desirable in heat shields, rocket motors and space-shuttle brake discs because of its high resistance to metal fatigue [1]. The diversity of applications of lithium has necessitated exploitation of its ores. Lepidolite, spodumene, amblygonite and petalite are som e of the lithium ores associated with mineralized pegmatite. However, the lithium contents of these ores may vary greatly and their grade largely depends on the composition and the degree of fractionation of the host pegmatitic fluid. Consequently, the resurgence of interest in the study of pegmatite occurrences in recent times is attributed to its rare metal endowments.

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Thus, mineralized pegmatites are sources of a broad spectrum of rare metals and rare earth elements like Ta, Nb, Sn, U, Th, Zr and Hf. The Ijero-Ekiti pegmatite is rare metal type and lepidolite subtype [2]. [3] highlighted the Nigerian pegmatite fields to include Oke-Ogun, Nasarawa-Keffi, Lema-Share, Kushaka-Birni Gwari, Kabba-Isanlu, Ibadan-Oshogbo and Ijero-Ekiti (Fig. 1).

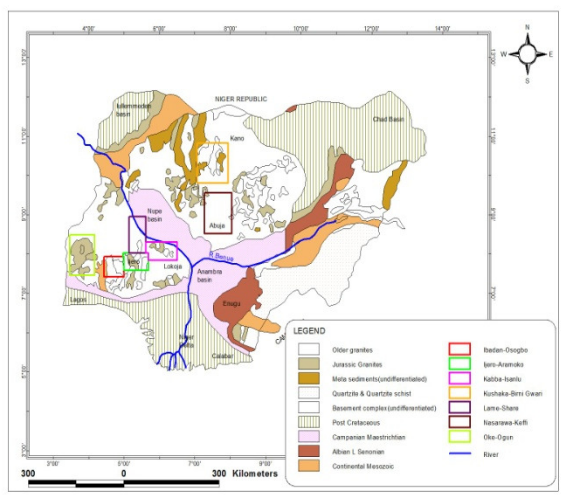


Fig.1: Map showing the Pegmatite fields of Nigeria (after [3].

Ijero-Ekiti and its environs are endowed with Tantalun-Niobium-Tin and Lithium metals and non-metallic deposits such as feldspar and kaolin hosted by muscovite and lepidolite respectively. This research is aimed at evaluating the industrial potential of the lepidolite by assessing its lithium content.

2.0 Regional Geological Setting

The geology of Nigeria consists of the basement rocks that are truncated by the sedimentary rocks in almost equal proportions. The crystalline rocks are of two age groups, the Precambrian age and the Younger Granites of Jurassic age. The sedimentary sequences are Cretaceous to Quaternary in age and spread across five sedimentary basins (Fig. 2).

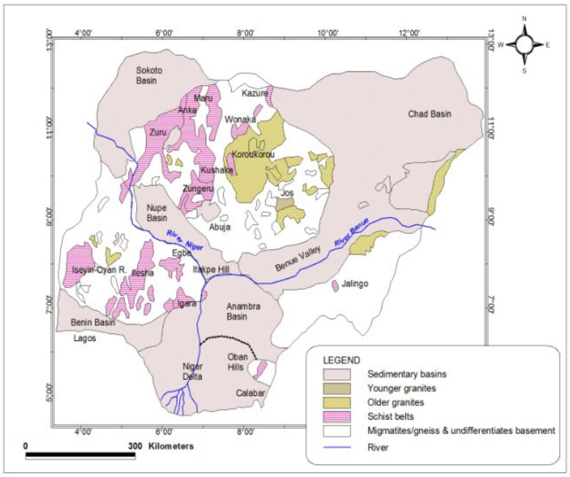


Fig. 2: Generalized Geological Map of Nigeria showing the Basement Complex, Schist Belts,

The Precambrian rocks (basement complex) form a prominent topographic feature of the country and underlie the study area, while the Younger Granites are restricted to the north central part around the Jos Plateau. The basement complex rocks fall into four lithological units: the migmatite gneiss complex, the schist belts , the Pan-African Granites (referred to as Older Granites) and the late intrusives . The migmatite gneiss complex comprise varieties of gneisses including biotite and hornblende gneisses, banded gneisses, augen gneisses, and granite gneisses with intercalations of quartzite and quartz schist. The schist belts comprise paraschists and meta-igneous rocks, schistose rocks, calc-silicates and talc-bearing rocks that occupy mainly N-S trending belts of low-grade supracrustal assemblages [4] . [5, 6 and 7], interpreted the schist belts as relics now preserved in synclinal keels of a once widespread cover of sedimentary rocks deposited in a single basin. However, based on the different lithological associations within the basins, [8, and 9] believed that these belts developed in separate basins indicating that they have all undergone the same deformational histories. Some of the belts contain gold mineralization, banded iron formation (BIF) or marble. The Pan-African Granites comprise rocks of wide spectrum of compositions ranging from granite to granodiorite and charnockite with minor pegmatite and dolerite dykes that belongs to the last stage of Pan-African magmatism [10]. The minor pegmatite plays host to the lepidolite mineral in Ijero-Ekiti.

3.0 Methodology of study

A systematic geological mapping and sampling were undertaken to localize the lepidolite mineralization. Thirty lepidolite samples 10 each from Oke-Asa, Ijero-Ekiti and Oke Igbo-Aba areas were collected and analyzed for their major and minor elements. The major elements were analysed using the Inductively Coupled Plasma -Atomic Emission Spectrophotometry (ICP-AES) method at the Activation Laboratories, Ontario while the trace element determination was carried out with X-ray Fluorescence model ORTEC 6111. The analytical procedure for the major elements determination involves the addition of 5ml perchloric acid ($HClO_3$), trioxonitrate (HNO_3) acid and 15ml of hydrofluoric acid (Hf) to 0.5g of the sample. The solution was stirred properly and allowed to evaporate as it is heated at a low temperature for three hours. 4mls of hydrochloric acid (HCl) was then added to the cooled solution and warmed to dissolve the salts. The solution is then introduced into the ICP torch as an aqueous aerosol. The light emitted by the ions in the ICP was converted to an electric signal by a photomultiplier in the spectrometer. The intensity of the electrical signal produced by emitted light from the ions was compared to a standard and the element concentrations computed. Parts of the samples were used for thin sectioning in order to determine the mineralogical composition of the studied lepidolite samples. Physical tests were conducted at Trevy Foundation, Lagos using the American Society for Testing and Materials D2487-83 procedures. The physical parameters evaluated are specific gravity, compressive strength, wet densities, water absorption capacities, porosity and pH. The results are presented in Table 3. The specific gravity tests were carried out using a pycnometer. 50g of dried lepidolite sample was put into the pycnometer and weighed (M_2). Distilled water was added to the sample in the pycnometer and was then filled to the brim and weighed (M_3). The cylinder is then emptied, cleaned and filled with distilled water to the same volume as the sample and weighed (M_4). The specific gravity is calculated as $SG = (M_2 - M_1)/(M_4 - M_1)\ (M_3 - M_2)$. Unconfined compressive strength was determined by statically loading a uniform cube of the mineral sample until it fractured, the load was applied across the upper and the lower faces of the sample. Wet densities were calculated as the difference between the densities of a fresh sample and sun-dried samples. The water absorption capacity is the difference between the weight of fired sample pellets of the mineral compared to that obtained by immersing the same sample in water for 24hrs and recalculated as a percentage. The pH was determined by mixing pulverized lepidolite sample and distilled water until they form a uniform paste in a test tube and a digital multiparameter portable meter (model Testr-35) inserted.

3.1 Lithological and structural framework

Ijero-Ekiti is located at 42km Northwest of Ado-Ekiti, the Ekiti State capital and about 350km NE of Lagos. The area lies between longitudes 5^o00^1E and 5^o07^1E, and latitudes 7^o46^1N and 7^o53^1N. The Ijero-Ekiti area is underlain by the basement complex rocks of Southwest, Nigeria .The local geology consists of the migmatite gneiss, quartzite, schist biotite gneiss, calc-gneiss, epidiorite, biotite schist, amphibole schist, granite and pegmatite. (Fig. 3).

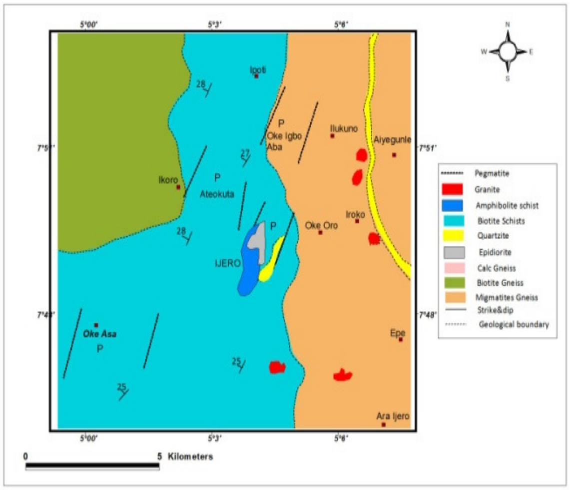


Fig. 3: Geological map of Ijero Ekiti area [2].

The migmatite gneiss occurs within the eastern part covering about two-fifth of the area, while biotite gneiss predominantly covers the northwest. The gneissic rocks are essentially highly foliated and denuded. Calc-gneiss and quartzite occupy a narrow NE-SW strip around Ijero-Ekiti town. Epidiorite occurs as the major ultramafic assemblage while amphibole schist and biotite schist occupy the central, low-lying area that is occasionally pulsed with granites and pegmatite intrusions now exposed due to prolonged weathering activities. The pegmatite occurs as very coarse-grained dykes, dykelets and sometimes of extensive dimension. Steeply dipping complex pegmatite around Ijero-Ekiti typically consists of an outer medium-grained microcline-albite-quartz-muscovite zone, an intermediate zone comprising coarse-grained microcline-albite-quartz, blocky microcline-quartz, coarse- grained quartz or lepidolite-quartz and finally, a core of coarse-grained muscovite-quartz and quartz [3]. Two stages are involved in the formation of lepidolite in pegmatite of Ijero-Ekiti area; A stage of emplacement, crystallization and differentiation of the melt that results in fractionation and isolation of rare-earth-element rich components of the magma. The second is a stage of metasomatic replacement during which there exists an interaction between the already crystallized outer parts of the pegmatite and the dissolved fluids in the remaining melt. Due to progressive enrichment in volatile components, the intermediate zone of the pegmatite now contains abundant tourmaline as well as cesium and lithium minerals. Thus, the typical secondary muscovite (lepidolite) forms good sites for lithium mineralization in the pegmatite. Like other micas, lepidolite occurs near the peripheral zone of the pegmatite and in the zone of feldspar and quartz intergrowth where it is associated with beryl and tourmaline. Other associates of lithium-bearing minerals in the pegmatite are cassiterite and columbite-tantalite [3]. The association of these minerals with lepidolite in the pegmatite may suggest pneumatolitic origin for the lepidolite. The concentration of lithium in ferro-magnesian minerals like micas, pyroxenes and amphiboles as it is for lepidolite may indicate a relatively high temperature of formation of lepidolite.

3.2 Field occurrence and petrography

Lepidolite from Ijero-Ekiti is typically violet to pinkish in colour. It has a layered structure, a perfect cleavage and equigranular texture. Oke-Asa area (8km southwest of Ijero-Ekiti) features an extensive and continuous lepidolite outcrop particularly on Oke-Asa Hill (Fig. 4).

Fig 4: Oke-Asa Fig lepidolite exhibiting medium grained equigranulur texture.

The lepidolite contains visible specks of black variety tourmaline (schorl) and muscovite. The mineral occurs at shallow depths in Oke-Igbo Aba (3km North of Ijero-Ekiti). Lepidolite from Oke-Igbo Aba area is characteristically pinkish in colour with very fine-grained silvery-white muscovite flakes. In this area, the mineral occurs at two different depths: an upper layer (1.6m thick) underlying a kaolin horizon and a lower layer (1.3m thick) sandwiched between a muscovite-quartz-rich layer and kaolin (Fig. 5).

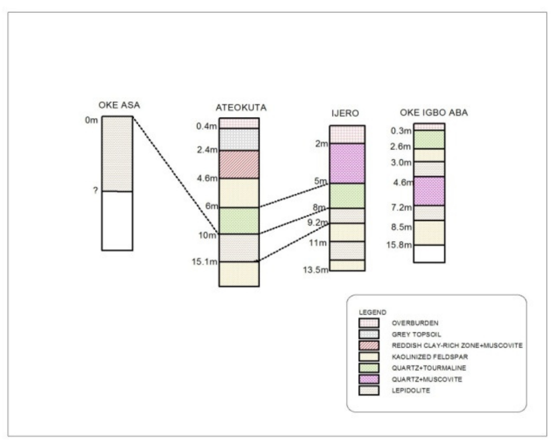
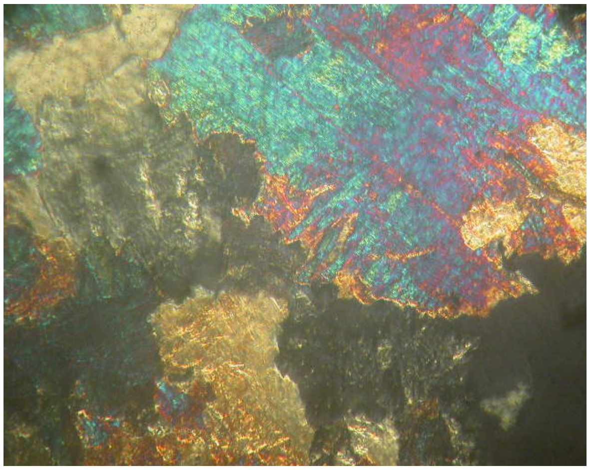


Fig. 5: Vertical sections through Lepidolite mineralization around Ijero-Ekiti.

Ijero-Ekiti features two levels of mineralization; an upper layer (1.2m thick) and a lower layer (2.4m) separated by a layer of gritty kaolin. Ateokuta area (500m west of Ijero-Ekiti) features a single layer of lepidolite with a thickness of 5.1m. Thin section study revealed the lepidolite around Ijero-Ekiti as tabular, pseudo-hexagonal crystals with scaly aggregates of cleavable masses that consists of large and extensive plates of secondary mica, associated biotite, and few muscovite minerals.The photomicrograph in Fig 6 shows that Lepidolite exhibits blue to purple colour under cross nicols ,biotite, a black colour and muscovite shows a brown colour.



4.0 Result and discussion

The modal analysis of the host pegmatite indicates that quartz content ranges from 32 to 42%, plagioclase (11-16%), orthoclase (15-22%), muscovite (10-16%),microcline 25-31 %, biotite (1-2%) and accessory opaque minerals dominated mainly by magnetite (1-2%), (Table 1).

Table 1: Modal analysis of the host pegmatite to the Lepidolite.

Minerals	S_1	S_2	S_3	S_4	S_5	Range	Average
Quartz	42	37	37	39	32	32-42	38.0
Plagioclase	13	12	16	15	11	11-16	12.8
Microcline	21	31	25	26	29	25-31	26.4
Muscovite	16	13	12	10	14	10-16	13.0
Biotite	1	-	2	2	-	1-2	1.0
Hornblende	5	3	1	4	5	1-5	3.6
Tourmaline	2	3	2	3	6	2-6	3.2
Opaque	-	1	2	-	1	1-2	1.0
Total	100	100	100	99	98		

Fig. 6: Photomicrograph of Ijero-Ekiti lepidolite in transmitted light showing large lepidolite L, (Purple and blue) and some associated biotite ,B (black) and muscovite M, (brown).

Quartz occurs as unaltered euhedral crystals, the feldspars are mainly microcline exhibiting polysynthetic and strong crosshatched twinning with perthitic intergrowth. Muscovite and biotite are platy and show strong birefringence colours. The result of the geochemical analysis in Table 2 shows that the samples have high concentration of SiO_2, Al_2O_3, Na_2O and K_2O over other oxides. The range of SiO_2 contents of the lepidolite in Oke-Asa is 49.49-50.16%), Oke-Igbo Aba (49.49-50.43%), and Ijero-Ekiti (57.87-57.81%).

Table 2: Chemical composition of lepidolite from Ijero-Ekiti area.

	Oke-Igbo Aba		Ijero-Ekiti		Oke-Asa	
Oxides (%)	**Average***	**Range**	**Average***	**Range**	**Average***	**Range**
SiO_2	49.99	49.49 - 50.43	58.40	57.87 - 57.81	49.83	49.43 - 50.16
TiO_2	0.01	0.01 - 0.02	0.02	0.01 - 0.02	0.02	0.02 – 0.03
Al_2O_3	27.83	27.52 - 28.37	23.02	22.85 - 23.29	28.24	27.95 - 28.37
Fe_3O_3	0.19	0.14 - 0.27	0.34	0.26 - 0.41	0.21	0.14 – 0.28
MnO	0.17	0.16 - 0.17	0.08	0.08 - 0.09	0.36	0.35 – 0.37
MgO	0.26	0.17 - 0.35	0.29	0.21 - 0.35	0.20	0.15 – 0.34
CaO	0.06	0.033 - 0.08	0.20	0.16 - 0.23	0.08	0.04 – 0.12
Na_2O	0.27	0.20 - 0.52	3.49	3.36 - 3.65	0.41	0.39 – 0.42
K_2O	10.06	9.78 - 10.25	5.86	5.73 - 6.01	9.41	9.14 – 9.59
P_2O_5	0.03	0.02 - 0.03	0.08	0.07 - 0.09	0.03	0,03 – 0.04
LOI	4.37	4.03 - 4.86	4.16	3.9 - 4.78	4.59	4.25 – 5.24
Trace Elements (ppm)						
W	0.8	0.6 - 1.0	0.5	0.4 - 0.6	1.2	0.8 – 1.7
Ta	0.36	0.29 - 0.44	0.03	0.02 - 0.04	0.6	0.4 – 1.0
Nb	3.1	2.81 - 3.5	3.7	3.5 - 3.9	2.9	2.6 – 3.7
Sn	15.2	12.88 - 17.5	13.7	12.5 - 15.4	16.8	13.5 - 19.5
Sr	1.4	0.81-1.84	0.8	0.5 - 1.0	1.7	1.5 – 1 .9
Li	1859	1580 – 1956	1656	1430 - 1870	1778	1685 – 1903
Be	243	195 – 264	279	138 - 390	219	202 – 2 52
Y	1.08	0.8 - 1.3	0.22	0.12 - 0.29	0.85	0.7 - 1.4
Ga	6.11	5.62 - 7.5	5.42	4.46 - 6.22	6.44	5.16 - 7.09
Cs	217	196 – 246	208	182 - 230	250	223 – 269
Rb	580	520 – 609	550	550 - 550	602	538 – 678
Zr	3.9	2.6 - 5.28	4.6	0.3 - 14	3.5	3.0 - 3.7
U	0.08	0.05 - 0.1	0.06	0.03 - 0.09	0.07	0.03 – 0.1
Th	0.07	0.06 - 0.1	0.08	0.06 - 0.1	0.10	0.05 – 0.2
Ba	11.53	9.7 - 13.8	8.9	8.1 - 10.5	8.6	7.17 – 10.87

* Average of ten samples

The silica values recorded for Oke-Asa and Oke-Igbo Aba areas are comparable, and lower than that of Ijero-Ekiti. Alumina ($Al_2O_{3)}$ content of Oke-Asa lepidolite (ca. 27.95-28.37%) is almost equal to that of Oke-Igbo Aba (ca. 27.52-28.37%) while Ijero-Ekiti has the least content (ca.22.85-23.29%) . K_2O value for Oke-Asa lepidolite (ca. 9.14-9.59%) is slightly lower than that of Oke-Igbo Aba (ca. 9.78-10.25%) but these two values are generally higher than the Ijero-Ekiti (ca. 5.73-6.01%) sample. The mean Na_2O value recorded for Oke-Igbo Aba lepidolite (0.27%) is lower than that of Oke-Asa (0.41%) while a grossly higher mean value is recorded for Ijero-Ekiti lepidolite (3.49%). Average MgO content of Oke-Igbo Aba lepidolite (0.26%) is comparable to that of Ijero-Ekiti (0.29%) whereas, Oke-Asa (0.20%) samples recorded a marginal lower value. TiO_2, MnO, CaO and P_2O_5 altogether account for less than 1.0% of the bulk composition in the samples from all the three locations. Average loss on Ignition values are 4.16%, 4.37% and 4.59% respectively in Ijero-Ekiti, Oke-Igbo Aba and Oke-Asa lepidolite. Trace elements composition of the lepidolite indicates higher lithium (Li), beryllium (Be), caecium (Cs) and rubidium (Rb) contents. Average lithium content of Ijero-Ekiti lepidolite (1656 ppm) is lower than Oke-Asa (1778 ppm), while Oke Igbo Aba (1859 ppm) has the highest mean value. The higher lithium content of Oke-Igbo Aba lepidolite may be attributed to the host pegmatite intruding into a gneissic basement as against the schistose bedrocks around Oke-Asa and Ijero-Ekiti areas. The pronounced enrichment in lithium content of all the lepidolite samples is attributable to lepidolite been an ore of lithium. Ijero-Ekiti lepidolite is the most enriched in beryllium with an average value of 279 ppm, while Oke-Igbo Aba and Oke-Asa areas record a mean value of 243 ppm and 219 ppm respectively. A mean value of 250 ppm for Oke-Asa sample represents the highest Cs content recorded in all the samples, as they are higher than 217 ppm and 208 ppm recorded for Oke-Igbo Aba and Ijero-Ekiti areas respectively. While Ijero-Ekiti samples record lower mean Rb (550 ppm) value, slightly higher values (580 ppm and 602 ppm) are recorded for Oke-Igbo Aba and Oke-Asa areas respectively. The average Sn content in Oke-Asa lepidolite (16.8 ppm) is slightly higher than Oke-Igbo Aba

(15.2 ppm) while Ijero-Ekiti (13.7 ppm) records the least value. Ta and Nb contents are generally low with Oke-Igbo Aba, Oke-Asa and Ijero-Ekiti areas recording 0.36ppm and 3.1ppm; 0.6ppm and 2.9ppm; 0.03ppm and 3.7ppm respectively. The low Ta and Nb values of all the samples may be attributed to the fact that Ta-Nb are preferentially concentrated in the muscovite phase rather than in the lepidolite. The result of the physical tests in Table 3 indicates that the specific gravity, compressive strength and wet density increase along a trend from Oke Igbo Aba down to Oke Asa where it reaches a maximum(Table 3).

Location	SG		CS (N/mm^2)		W.D(g/cm^3		WAC (%)		P (%)		pH	
Oke Igbo Aba	2.69	2.70	45.84	45.87	2.30	2.30	0.32	0.35	0.24	0.25	6.72	6.74
Ateokuta	2.71	2.73	49.93	49.78	2.35	2.33	0.25	0.21	0.17	0.18	6.75	6.72
Ijero	2.75	2.73	49.94	49.87	2.38	2.40	0.25	0.24	0.17	0.17	6.74	6.80
Oke-Asa	2.78	2.80	50.10	50.14	2.41	2.65	0.23	0.23	0.19	0.20	6.90	6.90

Table 3: Physical properties of the Lepidolite around Ijero-Ekiti

SG: Specific gravity; CS: Compressive strength; WD: Wet density; WAC: Water absorption capacity; P: Porosity The specific gravity value range between 45.84 and 50.14 N/mm^2, while the wet density values range between 2.30 and 2.65$g/cm^{3.}$ The water absorption capacities whose value range between 0.21 and 0.35% are low and effective porosities 0.17-0.25% are poor. PH values that range between 6.72 and 6.9 indicate that the mineral samples are formed in a mildly- acidic to neutral conditions.

4.1 Industrial application

Lepidolite (lithium mica) $K_2(LiAl)_5(Si_6Al_2)O_{20}(OHF)_4$ occurs in form like muscovite mostly in masses composed of small scales. The lepidolite also occurs in association with topaz and tourmaline within the tin –bearing pegmatite veins and the workable quantities are found in the intermediate zone of the pegmatite body. The high contents of SiO_2, Al_2O_3, and K_2O as well as unusual amount of lithium and microcline reveal the general geochemical characteristics of the lepidolite on which its industrial applications are based. Lithium minerals form sources of raw materials in the pharmaceutical companies for the making of lithium waters and Lithia tablets. Lithium is used in the making of the Edison storage batteries. Lithium compounds are useful in photography, in the area of welding aluminum and also serve as a purifying agent for helium and other gasses. It is found useful in alloy of aluminum, magnesium and zinc for light airplanes. Apart from these, lithium is used in the smelting of aluminum ores, reduction of shattering in glasses, and in heat transfer and in heat shields due to its high compressive strength. The modal analysis reveals that plagioclase, alumina and silica are abundant. The potash feldspar , usually microcline is a leading mineral in the granite pegmatite of Ijero that is presently exploited in commercial quantity. Lepidolite contains appreciable amount of Rb which is useful in determination of geological age according to Sr/Rb ratio.

5.0 Conclusion

Systematic geological mapping reveals that the pegmatite host to the lepidolite occurs as steeply dipping intrusive bodies into the basement of gneisses and schistose assemblages. The lepidolite mineral around Ijero-Ekiti is medium-grained and it exhibits equigranular texture. Thin section study indicates that the mineral is tabular, pseudo-hexagonal crystals with scaly aggregates of cleavable masses that consists of large and extensive plates. The geochemical analysis shows the abundance of SiO_2, Al_2O_3, Na_2O and K_2O over the other oxides while trace element composition indicates a higher enrichment in lithium (Li), beryllium (Be), cesium (Cs) and rubidium (Rb) relative to Ta and Nb. The Li content in the lepidolite from Oke-Igbo Aba is higher than those from Oke Asa and Ijreo areas. This could be due to the intrusion of the pegmatite into a gneissic host rock. The lithium compounds are used in a variety of ways in the pharmaceuticals, battery making and in alloy of aluminium, magnesium and zinc.

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