

## Original Research Article

### **GEOLOGIC STRUCTURES AND MINERALIZED PRECAMBRIAN PEGMATITE VEINS IN PARTS OF IGARRA SCHIST BELT SOUTHWESTERN NIGERIA.**

Comment [H1]: Mineralized into what?

#### **ABSTRACT**

Precambrian Pegmatite veins in Igarra were structurally analyzed in order to group the veins based on their mineralization potentials. Pegmatite veins are found more in Migmatite Gneiss and undifferentiated mixed rocks in the study area. They studied veins are predominantly oriented as dykes and sills structures while some were folded elliptical irregular shapes. Exposed studied veins have minimum length of 2.5m and maximum of 10m. A minimum width of 43cm and maximum of 2m were also recorded. Elements like strike directions analyzed using rose diagrams suggest the pegmatite veins were fault controlled. Results showed that the dominant strike directions of veins are mainly in the NE-SW and N-S directions. Also recorded were few veins which trend in the NW-SE direction which are likely remnants of Pre Pan-African orogenies in the study area. Modal composition of minerals from thin section results on samples shows they are predominantly feldspathic pegmatites with k-feldspar between (32 to 46%) with mean value of 40.9% and plagioclase (18 to 30%) with mean value of 21.5%. The NE-SW veins have more biotite than the NW-SE pegmatite veins. Perthitic structures (mask effect of albitic plagioclase) are associated with NE-SW veins. Sericitization of feldspars (hydrothermal alteration) was also seen in the NE-SW pegmatite veins. The mineral Tourmaline is associated with NE-SW veins as seen in thin section petrography while Sphene (Titanite) can be found in the NW-SE pegmatite veins.

Comment [H2]: What is the mineralization potential? We know that pegmatite veins are very often mineralized in rare earth elements such as Li, Ta, columbite-tantalite etc. In your case, what type of mineralization is involved?

Comment [H3]: Elements like strike directions analyzed using rose diagrams suggest that the emplacement of pegmatite veins is related to a dominant structural control

Key words: Pegmatite veins, Mineralization potentials, Rose diagrams, Modal composition, Tourmaline.

## 1.0 INTRODUCTION

The word pegmatite is derived from Homeric Greek (pegnymi) which means “to bind together”, in reference to the intertwined crystals of quartz and feldspar in the texture known as ‘graphic granite’ (London, D.; Morgan, G.B.2012). They display gray-whitish to pink colorations which suggest the presence of potassium feldspars in greater percentage than other minerals. Crystal size is the most striking features of Pegmatites, with crystals usually over 5cm in size. Individual crystal over 10m (33ft) long has been found, and many of the world’s largest crystals were found within Pegmatites. These include spodumene, microcline, beryl and tourmaline. (Schwartz, G.1928). Pegmatitic textures can develop in any intrusive igneous rock type from ultramafic, to granitic, to syenitic in composition. Most commonly, the term is used to refer to granitic pegmatites and is generally understood to refer to rock of overall granitic composition when it is used without a qualifying adjective e.g. gabbroic pegmatite(Simmons W.B; Webber K.L 2008).

Characteristically, they are inhomogeneous and show zones of different mineral assemblages. In some cases, crystal size and mineral assemblages are usually oriented parallel to the wall rock or even concentric for pegmatite lenses (London, D.; Kontak, D.J. 2012).Most pegmatites appear to form from a single intrusive magmatic event, but undergo a complex internal crystallization history that can result in a large range of grain sizes; consistent changes in mineral chemistry from wall zone to cores; increasing concentrations of fluxes, volatiles and rare elements and, in rare instances, the formation of pockets containing gem-quality crystals (Simmons W.B; Webber K.L 2008).

Depth-zone classification of granitic rocks has influence the classification of pegmatite in recent times. This is evidence in the articles published by Buddington (1959), and the Ginsburg & Rodionov (1960) and Ginsburg et al. (1979).These classifications categorized pegmatites according to their depth of emplacement and relationship to metamorphism and granitic plutons. (Simmons W.B,Webber K.L, 2008).

Cerný’s (1991) revision of that classification scheme is the most widely used classification of pegmatites today. Cerný’s (1991) pegmatite classification, which is a combination of emplacement depth, metamorphic grade and minor element content, has provided significant

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insight into the origin of pegmatitic melts and their relative degrees of fractionation. They are based on the pressure (and, in part, temperature) conditions that characterize their host-rock suites. They studied veins are predominantly oriented as dykes (fig.1) and sills structures while some were folded into irregular shapes (fig.2). Most times, they are emplaced concordantly to the host rock in tabular bodies injected in fault controlled fissures.

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Fig. 1. Multiple pegmatite dykes in migmatite gneiss. The length of book is 23cm

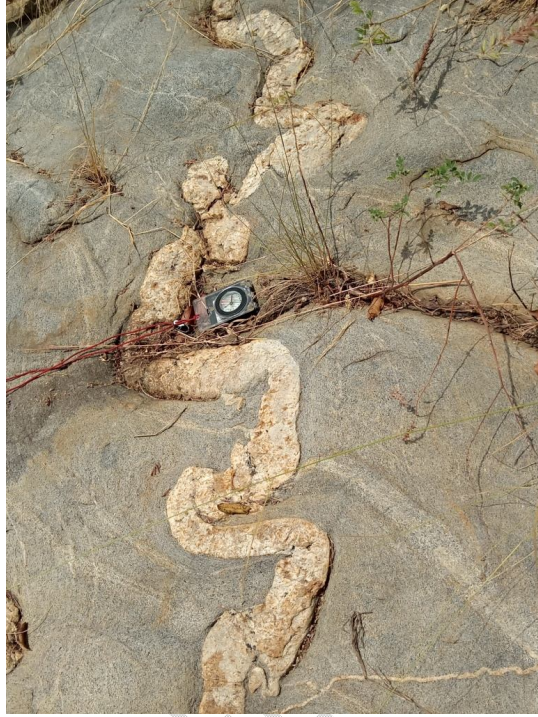


Fig.2 Recumbent folded pegmatite vein. The length of the compass is 14cm

The Igarra metasedimentary belt is well researched with publications in notable high index journals. There are many research works and publications on Igarra pegmatites but not much dwell on indentifying pegmatite veins and the orientation of structures that host valuable minerals in the area. This work therefore is an attempt to structurally analyze, identify and group mineralized pegmatite veins in the study area.

### **1.1 GEOLOGICAL BACKGROUND**

Nigeria is underlain by Precambrian Basement Complex rocks, younger granites of Jurassic age and Cretaceous to Recent sediments. The Basement rocks, which occupy about half of the landmass of the country, forms part of the late Archaean to early Proterozoic Pan-African mobile belt, situated between the West African Craton and the Congo Gabon Craton (Black 1980).

Within the context of the geology of the Nigerian Basement Complex, three broad lithological units are distinguishable. These are the migmatite-gneiss complex, the schist belts and the Pan-African older granite series (Elueze, 2000). The migmatite gneiss complex is a heterogeneous assemblage of predominantly amphibolite facies migmatites, orthogenesis, paragenesis and basic to ultrabasic rocks (Rahaman, 1988). The migmatite – gneiss is dominantly made up of quartzo – feldspathic gneiss that are predominantly biotite and / or hornblende – bearing and rarely pyroxene (Ekwueme and Kroener, 2005; Ukwang et al., 2003)

Igarra schist belt lies within the easterly end of the southwestern Nigeria basement complex around the Okene migmatite nucleus fig 3. The schist belt occurs as N-S trending zone of low to medium grade metasediments such as phyllite, semi-pelitic to pelitic schist, metagreywacke, metaconglomerate, quartzite and basic to ultrabasic metavolcanics (Rahaman, 1988; McCurry, 1989; Annor, 1998).

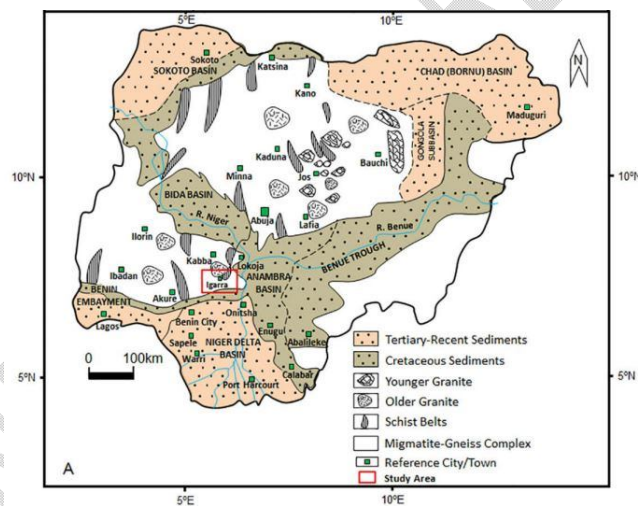
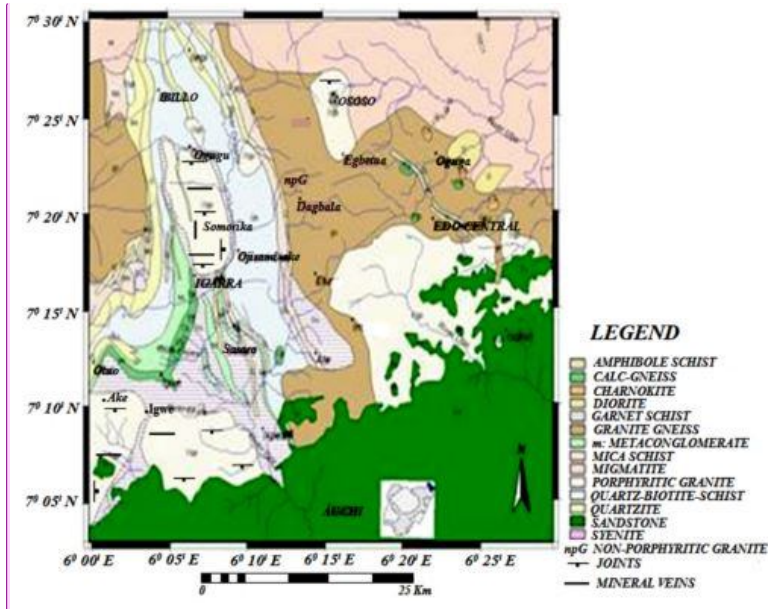


Fig.3 The study area in a geologic map of Nigeria (after Ogbe *et al*, 2018)



**Comment [H6]:** The map is blurry and the legend is illegible. This legend needs to be revised

Fig. 4 Geologic map of the study area (after Anifowose A.Y.B. *et al* 2006)

The local geology of the area can be divided into three major groups: (a) Migmatite and biotite hornblende gneiss, (b) Low grade metasediments (schists, calc-gneiss, marble, metaconglomerate and quartzites) and (c) Syn-to late tectonic porphyritic biotite-hornblende granodiorite, adamellites, charnockites and gabbros, while undeformed dolerite, pegmatite, aplite and syenite representing minor lithologies fig 4 (Olotu I.N., D.E.. Anyanwu, 2013. Isotopic data have revealed that the Basement Complex has been involved in several tectonothermal events, which include from the oldest Liberian, Eburnean, and Pan African orogenic events (Grant *et al* 1972; Ekwueme, 1987; Rahaman, 1988; Ekwueme and Kroener 2005).

## 2.0 MATERIALS AND METHODS

This study included both field and analytical works. Samples were collected from pegmatitic veins. Collections of samples were carefully performed, ensuring that samples were fresh and not altered by weathering. Efforts were made to make sure that sample sizes collected will be adequate for their intended use which includes petrographic analysis in order to achieve the aim of this study.

**Comment [H7]:** The fieldwork and analysis consisted of what? This part deserves to be better organized and well described. For example 2.1 field work and 2.2 analysis work

Structural elements such as strike direction, length and width of exposed pegmatite veins were recorded on field note and samples were collected from various sites visited. The samples were labeled and their locations (gps) were also marked fig.5 and table 1. Samples for petrographic analysis were collected in a pattern to represent all the rock types in locations considered important in achieving the objectives of the study. Some of the factors put into consideration for the samples selected includes freshness, size (>2kg), location (geographic spread), rock types.

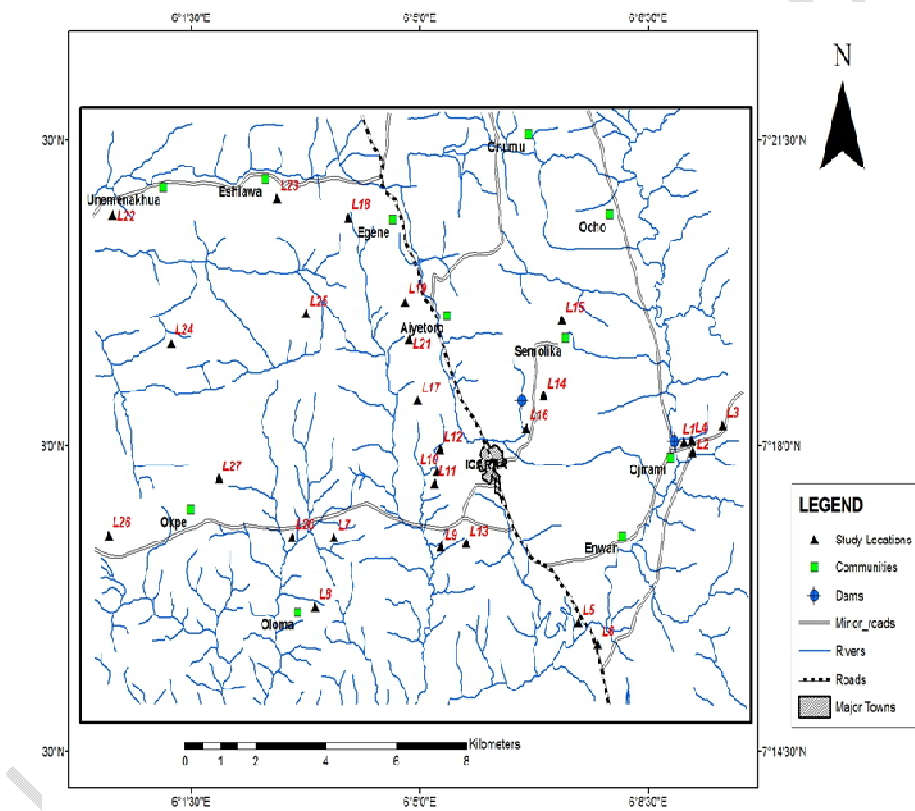


Fig.5 Drainage map of Igarra showing locations where samples were collected.

Table 1. Locations of sampled pegmatite veins.

Strike	Structure	Gps	Location	Length	Width
<del>N</del> 15°NE	dike	N07°16'48.26 <sup>II</sup> E006°01'38.92 <sup>II</sup>	Okpe	4.6m	43cm
<del>N</del> 38°NE	dike	N07°16'48.26 <sup>II</sup> E006°01'38.92 <sup>II</sup>	Okpe	6.2m	51cm
<del>N</del> 45°NE	sill	N07°16'72.16 <sup>II</sup> E006°01'68.92 <sup>II</sup>	Igarra	3.8m	47cm
<del>N</del> 18°NE	dike	N07°16'52.26 <sup>II</sup> E006°01'41.29 <sup>II</sup>	Okpe	2.7m	38cm
<del>N</del> 354°E W	sill	N07°20'54.41 <sup>II</sup> E006°02'38.40 <sup>II</sup>	Eshawa	12m	2.0m
<del>N</del> 20°NE	sill	N07°25'06.88 <sup>II</sup> 006°04'54.09 <sup>II</sup>	Ibilo	10m	1.5m
<del>N</del> 20°NE	sill	N07°25'06.88 <sup>II</sup> 006°04'54.09 <sup>II</sup>	Ibilo	14m	88cm
<del>N</del> 350°E NW	sill	N07°20'54.31 <sup>II</sup> E006°02' 38.32 <sup>II</sup>	Eshawa	12m	72cm
<del>N</del> 40°NE	sill	N07°16'72.28 <sup>II</sup> E006°01'68.42 <sup>II</sup>	Igarra	4.6m	64cm
<del>N</del> 20°NE	sill	N07°25'78.43 <sup>II</sup> 006°04'59. 39 <sup>II</sup>	Ibilo	8m	52cm

**Comment [H8]:** N15°E, N38°E etc when we say N15°E the structuralists know that the orientation is NNE-SSW and N45°E the orientation is NE-SW

## 2.4 SAMPLE PREPARATION

Samples of extracted pegmatites were selected and thin section petrography was prepared in the laboratory of Geology Department University of Calabar Cross River State Nigeria. The laboratory preparation of sample to be viewed and analyzed with polarizing petrographic

microscope, followed close monitored standard procedure. The aim of the petrographic analysis was to study the mineral compositions (in percentage) of the various rock samples. Thin (small) sample of rocks were cut with a diamond saw and ground optically flat. It was then mounted on a glass slide and then ground smooth using progressively finer abrasive grit until the sample is only 0.03mm thick. The method involved uses the Michel-Lévy interference colour chart. Typically quartz was used as the gauge to determine thickness as it is one of the most abundant minerals. Considerable cleanliness was observed throughout the entire process because a single grain of coarse material rubbed against the slide at the wrong time will often damage the thin section. A thin section properly grained normally shows a remarkable degree of transparency.

### 3.0 RESULTS AND DISCUSSION

They studied veins trend mostly in the NE-SW and occasional NW-SE directions (table 1). These field generated data were used in plotting a Rose diagram that showed the trends of the pegmatite veins (fig. 6). Ukaegbu 2003 reported the occurrence of pegmatite generally in N-S and NNE-SSW trend pattern in the Obudu area southeastern Nigeria basement complex. Akintola and Adekeye (2008) also reported the concentration of Pegmatites in a NE-SW trend extending from Ago-Iwoye in the southwest through Wamba-Jema'a to Bauchi area. Okunlola, O. A and Jimba, S. (2006) reported that Nigeria has a pegmatite belt which is beyond the confines of 400km NE-SW trending belt from Abeokuta, southwestern Nigeria to North Central Nigeria.



Fig. 7 Close-up view of a pegmatite vein with coarse interlocking grains and mica minerals

Comment [H10]: what is the nature of the surrounding rock?

Modal composition of minerals from thin section results on samples shows they are predominantly feldspathic pegmatites with k-feldspar mainly microcline and orthoclase between (32 to 46%) with mean value of 40.9% and plagioclase (18 to 30%) with mean value of 21.5% (table 2). A large amount of orthoclase in the rock is concealed by the mask effect of albitic plagioclase lamellae superimposed on it to form Perthitic structures.

Table 2 Modal composition of minerals from samples of pegmatites

Comment [H11]: With the size of minerals that are often larger than 5cm how do you manage to make a modal analysis under the microscope?

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
K-F(microcline+ orthoclase)	40%,	32%	45%	42%	46%	40%	45%	41%	38%	40%
Plagioclase	25%	18%	21%	18%	20%	22%	30%	20%	21%	20%
Biotite	15%	12%	10%	10%	8%	14%	10%	8%	12%	10%
Muscovite	5%	8%	2%	-	1%	3%	-	2%	-	2%
Quartz	15%	25%	22%	30%	24%	21%	15%	29%	22%	25%
Tourmaline		5%								
Sphene (Titanite)					<1					

### 3.1A NE/SW VEINS

The northeast/southwest pegmatite veins were predominantly oriented as sills and few recorded as dykes. The strike of the studied veins averages between 15°E and 45°NE (table 1). In the course of studying the petro-micrograph, it was noticed that large amounts of orthoclase were concealed by the mask effect of albitic plagioclase lamellae superimposed on it to form Perthitic structures (fig.8). Sericitization of feldspars were also well displayed in most of the studied

samples. Sericitization is the decomposition product of orthoclase feldspar to a secondary mineral that is a combination of potassium/mica. Sericite is produced by the alteration of orthoclase or plagioclase feldspars in an area that has been subjected to hydrothermal alteration. The decomposition structures are indications of the polycyclic deformation episodes that have taken place in the study area as recorded in literature.

Comment [H12]: Metamorphic transformation

Comment [H13]: Authors?

K-feldspar dominates over plagioclase and occurs in the larger crystal size sub-population in most of the studied samples. Cleavages were visible on the feldspars in PPL view. Quartz occurs in the smaller mineral grains, growing especially between the feldspars, and lacks well-formed crystal faces. Except for the micas which show some form of alignment, the grains generally lack fabric elements. There is also presence of tourmaline (fig.9) in the sample and the crystals range from euhedral to subhedral forms.

Comment [H14]: If you have actually seen tourmaline it could suggest hydrothermal alteration

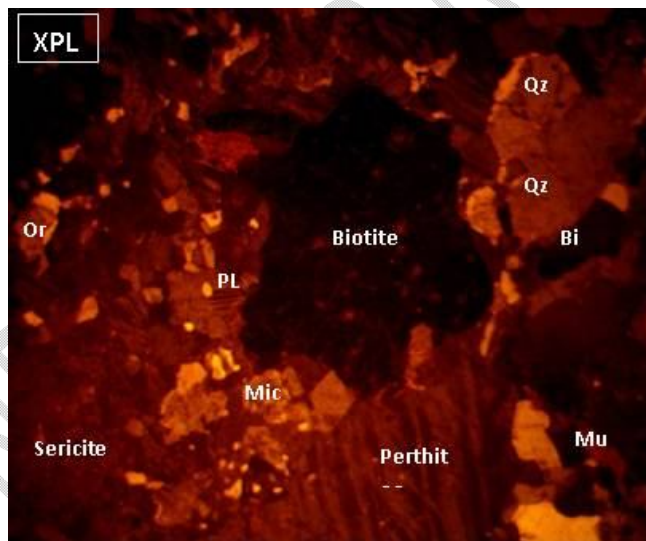


Fig.8 Photomicrograph under xpl showing mask effect of albitic plagioclase and Perthitic structures.

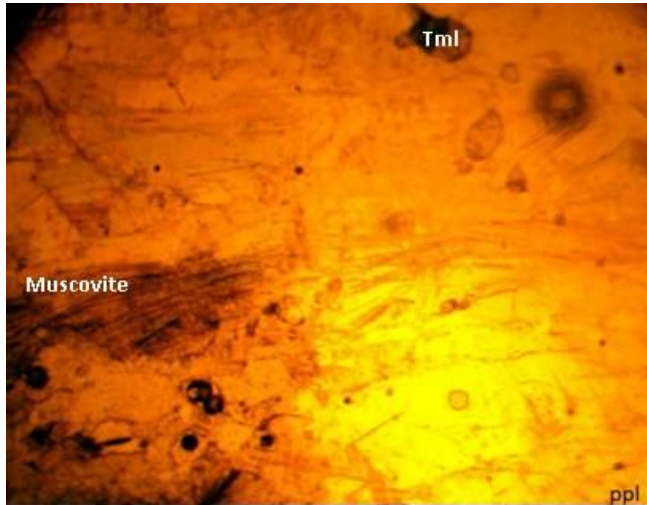


Fig.9 Photomicrograph under ppl showing the mineral **tourmaline**

There is also presence of vermiform intergrowth of quartz in plagioclase creating a myrmekitic feature in few of the studied photomicrograph. Such structures are typical of late stage activities in igneous rocks if the two minerals grew simultaneously, or indicate replacement activity driven by hydrothermal alteration when they develop at different times.

### 3.1 **NW/SE VEINS**

The northwest/southeast pegmatite veins were predominantly oriented as sills and are fewer. The strike of the studied veins averages between  $350^{\circ}$  and  $354^{\circ}$  (table 1). The samples studied were typically coarse-grained and bears a few spindle-shape grains of **Sphene (Titanite)** characterized by high relief (fig10). Muscovite in its usual high interference colour was also studied occurring commonly as an inclusion with quartz in feldspar. **Feldspars** predominate in the studied samples. Feldspar microstructures such as two-feldspar intergrowths and growth twinning were quite noticeable. The untwinned orthoclase was distinguishable from quartz in PPL by its surface alteration features which was not present in quartz. Quartz grains were nearly equigranular, with feldspar surrounding quartz crystals (fig10).

**Comment [H15]:** Which ones? plagioclase or orthoclase or microcline?

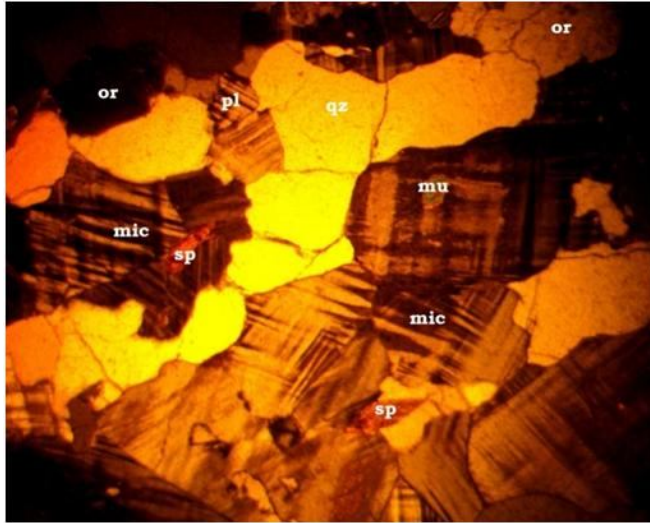


Fig.10 Photomicrograph under xpl showing spindle-shape grains of **Sphene (Titanite)**

#### 4.0 CONCLUSION

Igarra metasedimentary terrain falls within the eastern part of the South-Western block of the Nigerian Basement Complex believed to be Precambrian in age. The area is believed to have evolved as a result modern plate tectonic processes (Burke and Dewey, 1972; Affaton et al, 1992). Igarra is believed to have undergone multiple thermo-tectonic events in the past resulting to the deformation and emplacement of the formations as seen the area. Sericitization and decomposition of feldspars as a result of hydrothermal alteration were all pointers to the impact and effect or indications of the polycyclic deformations that have taken place in the study area in a micro level. Since the Nigeria basement complexes have similar deformation history, and it has been researched and recorded that pegmatite veins in other areas trend similarly in same directions, research should be carried out to ascertain if their mineralization are equally same. Further works should also be carried out in the area to find out if the pegmatite veins are of the same age. Similarly, research should also be carried out to know if some of the veins we tag as pegmatites were originally hydrothermal veins deformed by the polycyclic thermo-tectonic events in the area.

**Comment [H16]:** It would be advisable to revise the conclusion taking into account that the potential for mineralization is not proven in your data, as it is common to see accessory minerals such as sphene, zircon etc. in these rocks

## REFERENCES

**Annor, A.E., 1998.** Structural and chronological relationship between the low grade Igarra schist and adjoining Okene Migmatite-Gneiss terrain in the Precambrian exposure of Southwestern.

Black R. (1980) Precambrian of West Africa [J]. Episode. 4, 3 – 8.

**Buddington, A.F. (1959):** Granite emplacement with special reference to North America. Geol. Soc. Am., Bull., 70, 671-747.

**Cerný' P., 1991:** Rare-element granitic pegmatites. Part 1: Anatomy and internal evolution of pegmatite deposits. Part 2: Regional to global environments and petrogenesis. Geosci. Canada, 18, 49- 81.

**Ekwueme, B. N and Kroener, A., 2005.** Single Zircon ages of migmatitic gneisses and granulites in the Obudu plateau: Timing of granulites-Facies metamorphism in Southeastern Nigeria. Journal of Africa Earth Science. (In press).

**Ekwueme, B. N., 1987.** Structural orientation and Precambrian deformational episodes of Uwet area, Oban Massif, SE Nigeria. Precambrian Research. 34, 269-289.

**Elueze, A. A., 2000.** Compositional appraisal and petroctectonic significance of the Imelu banded ferruginous rock in the Ilesha schist belt, southwestern Nigeria. *Journal of Mining and Geology*. 36, (1): 8-18. Nigeria. *Journ. Mining and Geology* 34, 197-194.

**Ginsburg, A.I. & Rodionov, G.G. (1960):** On the depth of formation of granitic pegmatites. *Geol. Rudn. Mestorozhd.*, 45-54 (in Russian).

**Ginsburg, A.I., Timofeyev, LN., Feldman, L.G. (1979):** Principles of geology of the granitic pegmatites. Nedra, Moscow 296 p. (in Russian).

**Grant, N. K., M. Hickman, F. R., Burkhotder and Powell, J. L., 1972.** Kibaran metamorphic belt in Pan-African domain of West Africa. *Nature Physical Science*. 238, 90-91.

**London, D.;Morgan, G.B (2012).** The pegmatite Puzzle . *Elements*. 8(4): 263 – 268

**London, D.; Kontak, D.J. (2012).** Granitic Pegmatites: Scientific Wonder and Economic Bonanza. *Elements*. 8(4): 257 – 261.

**Mccurry, P., 1989.** A general review of the geology of the Precambrian to Lower Paleozoic rocks of Northern Nigeria. In: Kogbe, C.A. (Ed.), *Geology of Nigeria*, Rock View, Jos, 13-37.

**Okunlola, O. A and Jimba, S., 2006.** Compositional trends in relation to T-Nb mineralization in Precambrian pegmatites of Aramoko Ara-Ijero area Southwestern Nigeria. *Journal of Mining Geology*. 42, (2): 113-126.

**Oloto I.N., D.E.. Anyanwu, 2013.** Petrology of IbilloMagongo area of Igarra, Edo State, Nigeria. *Adv. Applied Sci. Res.*, 4: 140-145

**Rahaman, M.A., 1988.** Recent advances in the study of the basement complex of Nigeria. In: Oluyide, P.O., Mbonu, W.C., Ogezi, A.E., Egbunike, I.G., Ajibade, A.C., and Umeji, A.C., (Eds), *Precambrian geology of Nigeria*, Geological Survey of Nigeria Publication, Kaduna, 11-43.

**Schwartz, G. (1928).** The Black Hills Mineral Region. *American mineralogist*. 13: 56-63.

**Simmons W.B, Webber K.L (2008).** Pegmatite genesis: State of the art. *Eur. J. Mineral*. 2008, 20, 421–438 Published online August 2008.

**Ukwang, E. E., Ekwueme, B. N and Horsley, R. J., 2003.** Petrology of granulite facies rocks in Ukwartong area of Obudu Plateau, Southeastern Nigeria. *Global Journal of Geological Sciences*. 1 (2): 159-167.

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