PETROCHEMICAL STUDIES OF PEGMATITES AROUND AWO, SOUTH WESTERN NIGERIA

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ABSTRACT

Pegmatites around Awo bear valuable economic minerals; the rocks which trend mostly in the North East/South West are associated with other rock types like syenite, quartzite, porphyritic granite, biotite gneiss and migmatite gneiss. This study involves geological mapping of the study area showing its associated rock types, petrographic studies and chemical analysis were also considered. Five representative samples of the rock were investigated for their geology, petrography and geochemistry. Geological field mapping of the study area was carried out by collecting various rock types, studying their field occurrences, structural components and hand specimen observation. Petrographic studies entailed cutting polished sections of the rocks to identify each constituent mineral under petrological microscope while the geochemistry involved carrying out X-ray Fluorescence spectrometry analytical method on the digested samples at ACME Laboratory in Canada. The Petrographic studies revealed the modal composition of constituent minerals like microcline, plagioclase, quartz, mica (muscovite +/- biotite), opaque minerals and accessory minerals in the pegmatites. Geochemical analysis showed the mean weight of the major oxides like SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO , Na_2O, K_2O, and P_2O_5. The AFM diagram plot falls on the calc-Alkaline rock suite while the harker's plot revealed that the plots between and SiO_2 and other major elements are derived from the same geological environments. The study generally showed that the pegmatites of the study area bear semblance with pegmatites from other parts of the basement complex of South Western Nigeria with proven mineralisation.

Keywords: *Pegmatites, Petrological, Calc-Alkaline, Harker's plot, Opaque minerals.*

INTRODUCTION

Pegmatites around Awo were found to possess various gemstones like beryl, tourmaline, and other economic minerals like tantalite, columbite, clay minerals, feldspars, construction gravels and silica sand. The increase in global demand for these economic minerals has led to keen interest in prospecting for mineral deposits from different areas of south western Nigeria (Okunlola and Oyedokun, 2009). Therefore, there is need for the rocks in the area to be studied for economically valuable minerals that can be exploited from them. Pegmatites are important because they are classic source of broad spectrum of rare earth elements such as Lithium (Li), Rubidium (Rb), Caesiun (Cs), Berylium (Be), gallium (Ga), Scandium (Sc), Yttrium (Y), Tin (Sn), Niobium (Nb), Tantalum (Ta), Uranium (U) and Thorium (Th) from which various economic minerals originated from (Cerny, 1994).

This study is targeted at conducting geological mapping of the area with a view to identifying different rock types and to study the field, compositional, structural, and textural relationship among the rock varieties available in the area. Investigation also involves petrographic examination and geochemical analysis of the samples selected. Much consideration is given to the major oxides.

Geology of the study area

The study area which is a part of the Precambrian basement complex is made up of different rock types which include pegmatite, syenite, porphyritic granite, biotite gneiss, banded gneiss, migmatite gneiss, quartzite and quartz schist. Pegmatite is the predominant rock type in the area (fig 1). The rock body which intrude into syenite mostly trend in the NE/SW direction in Nigeria, occurs as irregular or massive bodies, veins and sometimes as a cross-cutting discordant dykes in other rock units like migmatite and banded gneisses. These dykes and veins range from few centimeters to tens of meters.

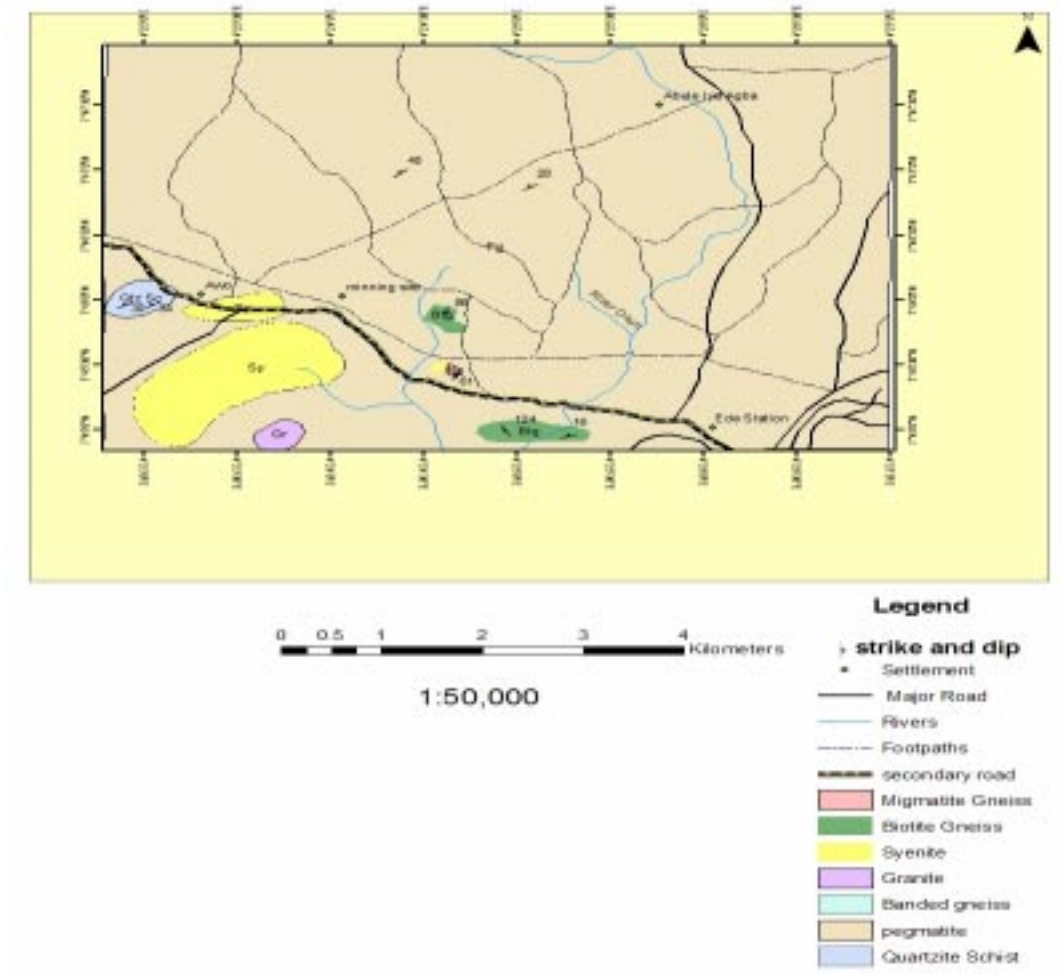

Fig 1: Geological Map of the study area.

Pegmatites within the vicinity of the mining site have been deeply weathered revealing the resistant, fractured quartzitic bodies. Evidence of weathering is noticeable as the less resistant feldspars display variegated colours which is between red and off-white. Hand specimen examination of the fresh and un-weathered samples show interlocking, randomly oriented crystals of feldspars (microcline and plagioclase), quartz, micas (mostly muscovite), opaque minerals and other accessory minerals in varying proportion. Rod-like, prismatic crystals of black, semi-precious tourmaline occur in some outcrops as interpenetration within the pegmatite. Garnets of varying sizes also occur in some pegmatites, the garnets have lost their brownish brilliant luster due to prolonged exposure to the atmospheric condition. Structural components of the pegmatites include veins and joints which are characteristics of the Pan-African orogeny. The veins are quartzitic, feldspathic and quartzofeldspathic in composition. Sets of joint which appear as straight and cross-cutting also occur in the rock bodies, the joints are orientated mostly in the NE/SW directions.

METHODOLOGY

Geological field mapping was undertaken in order to collect, identify and study the field occurrences cum structural relationship of all the rock types present in the study area. Fresh and un-weathered rock samples were broken for hand specimen examination. Preliminary observation and identification of each constituent mineral were carried out using magnifying lens. Field data measurements like measuring strike and dip directions with compass-clinometer, taking the coordinates of every sampling point and location using Global Positioning System (GPS) was carried out. Other structural imprints like joint trends, dimension of zenoliths, veins, concordant and discordant dykes, were also recorded.

For the petrographic studies, five rock samples were cut into chips with a micro-cutting machine and subsequently polished on glass ground plate using carborundum to obtain required thickness and a perfectly smooth surface, the cut rock samples were thereafter mounted on a clean glass slide with adhesive (Rollison,1992). The prepared slides were examined under the petrological microscope to identify mineralogical features that were not hitherto seen with unaided eyes in the rock samples. Laboratory analysis was achieved by pulverizing selected samples into powder using porcelain pestle and mortar at the Geochemistry Laboratory, Department of Geology, University of Ibadan in Nigeria. The pulverized samples were assayed for major elements using X-ray Fluorescence Spectrometry at ACME Laboratory, Ontario, Canada.

RESULT AND DISCUSSION

Field observation showed that Pegmatite which serves as host for these economic minerals occur in association with other rock types like Syenite, biotite gneiss, banded gneiss, migmatite gneiss, granite and some pocket of schistose rocks. Pegmatites are known to host many metallic and non-metallic minerals that are of great economic

benefits. Pegmatites are wide spread throughout the basement complex of Southwestern Nigeria. Precambrian pegmatite occurs mostly in the Western half of Nigeria along NE-SW pegmatitic trending belt (Jacobson and Webb, 1964).

The mineralogy of pegmatite compose of feldspar, quartz, mica and other accessory minerals in varying composition, their sizes vary from veinlet of about few millimeters bodies to a few kilometers in width. Muscovite is the more abundant mica occurring in the pegmatite of the study area while biotite is very few. Minerals in pegmatite have large crystals, which are identifiable and recognizable in hand specimen. Two different pegmatites are observed around the area, they are barren and complex pegmatite.Barren pegmatite has no evidence of mineralization, it contains minerals like quartz, feldspars (microcline and orthoclase), micas (mostly muscovite). Muscovite is sometimes compacted into dark colouration. Complex pegmatite contains minerals like beryl, tantalite, columbite, tourmaline, garnet among others.

Mining activities in the area are until now artisanal in nature. The mining site was opened up by miners using bulldozers, drilling equipment; pick axes, diggers, and shovels. Apart from economic minerals that are available, quarry sand, construction boulders and gravels were also exploited. These sand and gravel were carried and washed at nearby stream causing a devastating damage to the aquatic lives and also polluting the stream and rivers in the area. This study is targeted at conducting geological mapping of the area with a view to identifying different rock types and to study the field, compositional, structural, and textural relationship among the rock varieties available in the area. Investigation also involves petrographic examination and geochemical analysis of the samples selected. Much consideration is given to the major oxides

It could be clearly seen from the geological map figure 1 that pegmatite which exists as intrusion syenite is the predominant rock type available in the area. Pegmatite which trends NE-SW direction are found in different forms like vein, irregular or massive bodies and sometimes as a cross cutting discordant dyke. Pegmatite that exists as vein and dyke are very common in other rock units like banded gneiss and migmatite gneiss. Their relationship with the host rock could be cross cutting, oblique, or sometimes concordant to foliation or to general trend. These pegmatite dyke and vein range from few centimeter to ten of metres. In some cases there are abrupt terminations. The pegmatites within the vicinity of the mining site at Awo have been extensively and deeply weathered revealing the highly resistant fractured quartzitic bodies. The quartzites are of different varieties. Those that are common include the transparent rock crystals, the milky white quartz, smoky quartz which could be irregular in shape and in some cases assume the hexagonal crystal shapes. The topography of the mining site associating with pegmatite is made up of the slopy high land deeply weathered pegmatite and flat lying or low lying unweathered pegmatite outcropping discontinuously around the mining site. Evidence of deep weathering is noticeable at the mining site with the excavation of kaolin whose colour

varies from red to off-white. Hand specimen observation of the unweathered pegmatite in the study area show interlocking grains of crystals of feldspar, quartz and micas commonly muscovite. Crystals of black tourmaline (schorl) are embedded within some pegmatitic bodies, some pegmatitic bodies are also found to contain garnets of varying sizes. These garnets have lost their brilliant lustre due to long exposure to the atmospheric condition. Field observation showed that Pegmatite which serves as host for these economic minerals occur in association with other rock types like Syenite, biotite gneiss, banded gneiss, migmatite gneiss, granite and some pocket of schistose rocks. Pegmatites are known to host many metallic and non-metallic minerals that are of great economic benefits.

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Complex pegmatite contains minerals like beryl, tantalite, columbite, tourmaline, garnet among others. Mining activities in the area are up till now artisanal in nature; the mining site was opened up by miners using bulldozers, drilling equipment, pick axes, diggers, and shovels. Apart from economic minerals that are available, quarry sand, construction boulders and gravels were also exploited. These sand and gravel were carried and washed at nearby stream causing a devastating damage to the aquatic lives and also polluting the stream and rivers in the area.

Modal Analysis: Based on the hand specimen and petrographic observation, the modal composition of constituent minerals in the five representative samples of pegmatite vary from location to location, the modal percentage of quartz, feldspar, micas (muscovite) are as shown on table 1. Other accessory minerals in pegmatite include zircon, apatite, sphene, ilmenite, and magnetite occurs in negligible amount which in most cases is less than 1%.

Table1: The modal composition of constituent minerals in pegmatite.

Constituent Minerals	Sample A	Sample B	Sample C	Sample D	Sample E
Feldspar	21.5	25.7	39.5	79.0	60.5
Quartz	52.5	62.0	40.0	29.5	6.9
Mica	25.6	12.0	20.0		32.1
Other	0.4	0.3	0.5	1.5	0.5
Total	100%	100%	100%	100%	100%

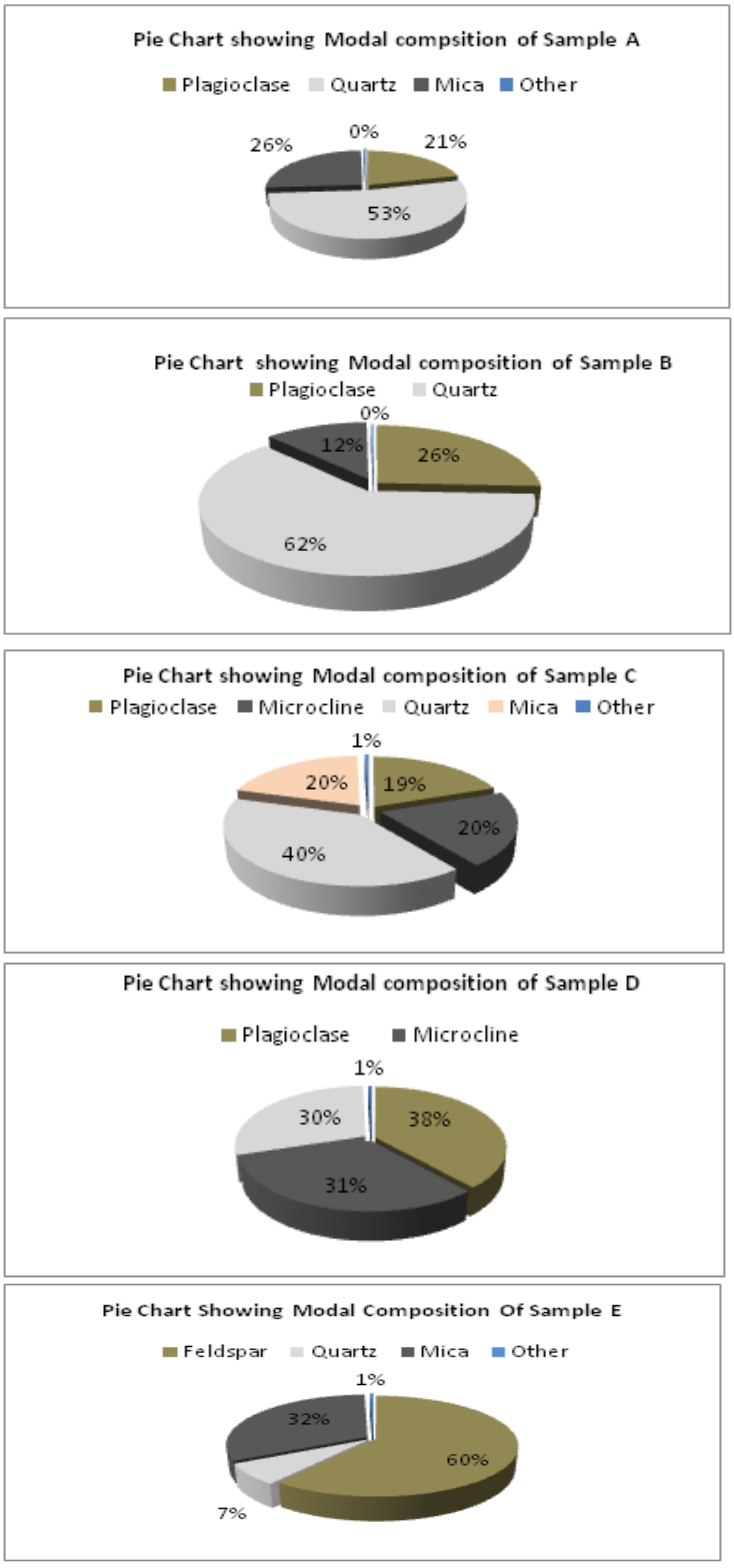


Fig 2: Showing pictorial representation of the constituent minerals

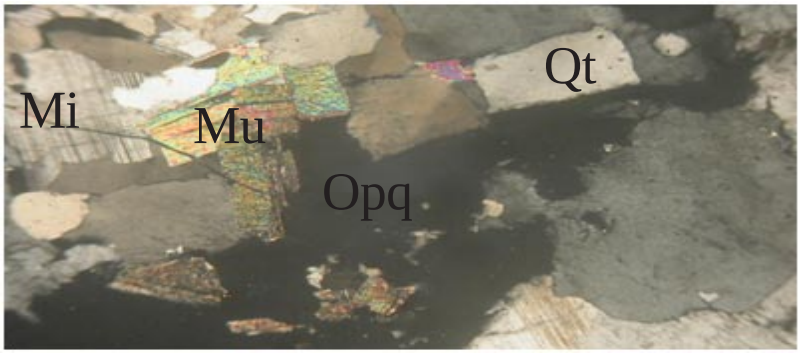
Table 2: Showing mean modal composition of Aramoko, Ijero and Awo Pegmatites. (modified after Okunlola, 2008)

Mineralogical Composition	Aramoko Ekiti %	Ijero Ekiti %	Awo %
Quartz	46.1	38.0	36.2
Microcline	32.7	6.4	45.2
Albite	2.6	13.0	(Microcline+ Albite)
Muscovite	14.5	30.0	21.7 (excluding Lepidolite)
Lepidolite	2.1	9.0	
Tourmaline	1.0	1.8	Not determined
Topaz	0.5	0.6	Not determined
Opaque	0.5	1.2	3.2 (Opaque+ other accessory mineral)
Total	100.00	100.00	100.00

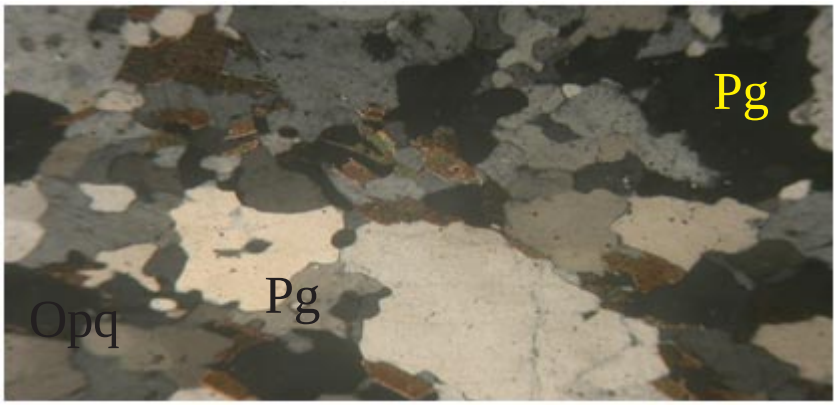
Mean modal composition of constituent minerals in pegmatites of the study area was compared with other areas whose modal composition has already been determined. The areas are Aramoko Ekiti and Ijero Ekiti. It could be seen on Table 2 that modal composition of quartz from Aramoko Ekiti which is 46% is the highest while composition of feldspar is the highest for Awo pegmatite with a modal percentage of 45.2%. Ijero Ekiti pegmatite has the highest percentage of muscovite with a modal value of 30.0%.

Petrographic Studies: Microscopic examination of the pegmatite samples in cross polarized light revealed the presence of varying composition of constituent minerals such as microcline, plagioclase, quartz, muscovite and opaque minerals. Plagioclase is the most abundant, its cleavages are noticeable, and its thin, bright and parallel lamella of polysynthetic twinning conform to the albite law (fig 3). The microcline shows cross hatched, tartan twinning (fig 3). Microcline and plagioclase possess randomly oriented euhedral crystals. Quartz shows an irregular, subhedral body which occupies the interstitial space of plagioclase. Graphic intergrowth is noticed between quartz and plagioclase (fig. 3). Muscovite interpenetrates the quartz and feldspars. The basal cleavage is perfect. Muscovite maintains a brownish green to pinkish blue colouration. The feldspars appear cloudy; this could be due to the alteration processes in them. Quartz maintains grayish to whitish colouration. Generally, pegmatites of the study area are both of simple and complex varieties, the complex varieties are similar to those described by Okunlola (2006).

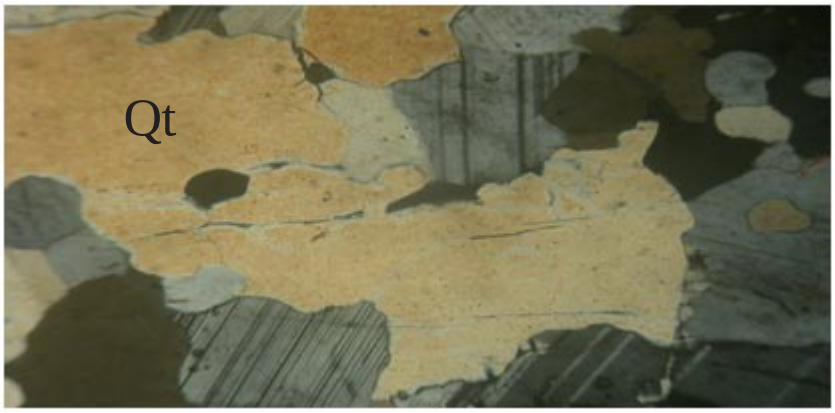
Cross polarization X 40 Pg-Plagioclase, Mi-Microcline, Qt-Quartz, Opq-Opaque mineral



Cross polarization X 40 Pg-Plagioclase, Mi-Microcline, Mu-Muscovite, Qt-Quartz, Opq-Opaque mineral



Cross polarization X 40 Mu-Muscovite, Pg-Plagioclase, Qt-Quartz, Opq-Opaque Minerals



Cross polarization X 40, Pg-Plagioclase, Qt-Quartz, Opq-Opaque mineral

Fig 3: Showing photomicrographs of the pegmatite samples

Geochemistry: Average weight percentage for major oxides like Sio_2, Al_2o_3, Tio_2, Fe_2o_3, MnO, MgO, CaO, Na_2O, K_2O were obtained using the X-ray Florescence Spectrometry technique. The data as shown on table 3 were compared with values obtained for similar rock type whose chemical compositions have been established.

Table 3: Geometric means of the major elements of the study area

Major element	Range (wt %)	Average (wt %)
SiO_2	65.7 -77.6	71.92
TiO_2	0.0 - .36	0.11
Al_2O_3	12.91 -17.64	15.4
Fe_2O_3	0.41 -3.17	1.18
MnO	0.02 -0.15	0.06
MgO	0.01 -0.73	0.19
CaO	0.22 -2.75	0.99
Na_2O	3.34-8.56	5.28
K_2O	0.84 -6.82	3.59
P_2O_5	0.08 -0.68	0.14

Geochemical data for the major elements showed an average value of 71.92% for SiO_2. The high silica content is due to the high concentrations of Aluminosilicates and silica minerals which include quartz, Muscovite, Alkali and Plagioclase feldspar. The values of other major elements from the study area are Al_2O_3 (15.4%), Fe_2O_3 (1.18%), MnO (0.19%), CaO (0.99%), Na_2O (5.28%), K_2O (3.59%), TiO_2 (0.11%), P_2O_5 (0.05%). SiO_2, Al_2O_3 and K_2O with values 71.92%, 15.40% and 3.59% respectively from the bulk constituent of the oxide composition. The values for the three major oxides fall within the range of values of other Ta-Nb pegmatites of Nigeria (Okunlola, 2005).

The mean values obtained for trace elements around the study area are Rb (1410 ppm), Cs (85 ppm), Y (167 ppm), Nb (89 ppm), U (0.11ppm), Th (0.20 ppm). These values are generally higher than those obtained for Ibadan-Oshogbo field with average in the following trace elements, Li (35 ppm), Rb (300 ppm), Cs (25 ppm), Be (156 ppm), Ba (215 ppm), Y (25 ppm) Sn (48 ppm), Nb (37 ppm), Ta (83 ppm), U (0.08 ppm) and Th (0.08 ppm). It is generally observed that pegmatites of Awo are enriched in the trace elements as mentioned above.

Table 4: Comparative mean chemical compostion of Pegmatites samples in wt%

Oxides	Oke-Ogun	Ijero- Aramoko	Ibadan-Osogbo	Kabba- Isanlu	Awo Area
SiO_2	72.11	76.1	72.1	73.5	71.92
K_2O	3.15	2.95	3.88	1.4	3.59
Al_2O_3	16.21	16.3	18.1	17.24	15.4
Fe_2O_3	1.06	1.85	0.19	0.81	1.18
MnO	0.01	0.07	0.01	0.1	0.06
MgO	0.35	0.44	0.05	0.09	0.19
CaO	0.01	0.25	0.17	0.38	0.99
Na_2O	4.2	3.85	4.75	5.0	5.28

Analytical data for major elements of Pegmatites from Awo were compared with several fields of Ijero-Aramoko, Ibadan-Oshogbo, Oke-Ogun and Kabba-Isanlu. The geochemical data of major elements from these fields as acquired by Irvine and Baragat (1971), Kuno (1968), Okunlola *et al.* (2001, 2002, 2005, 2008) are summarized on the table 4 above. Values obtained for major elements in Awo pegmatites conform with the values recorded from other fields particularly Ibadan-

Oshogbo as seen on table 4. Comparing the pegmatite samples in Awo area with those of Oke-Ogun, Ijero-Aramoko, Ibadan-Oshogbo and Kabba-Isanlu, the pegmatite's of Awo appear to be higher in Na_2O, CaO and lower in SiO_2, K_2O, Al_2O_3, MgO, Fe_2O_3, and K_2O. Concentration of K_2O shows a higher percentage than that of Oke Ogun, Ijero-Aramoko and Kabba-Isanlu but its lower in percentage compared to Ibadan-Osogbo.

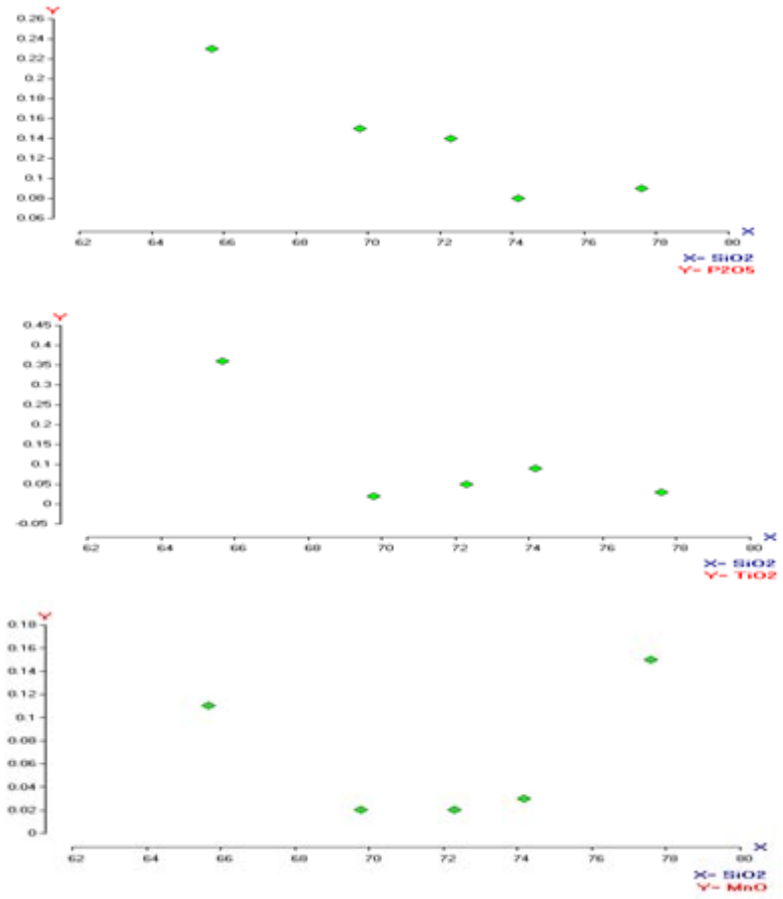
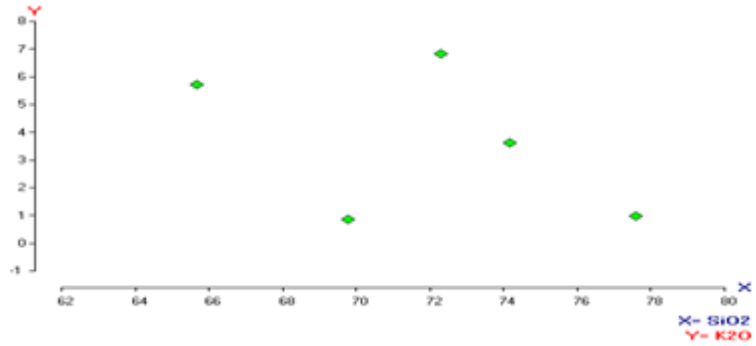


Fig 4a: Harkers diagram for SiO_2 vs P_2O_5, TiO_2 and MnO



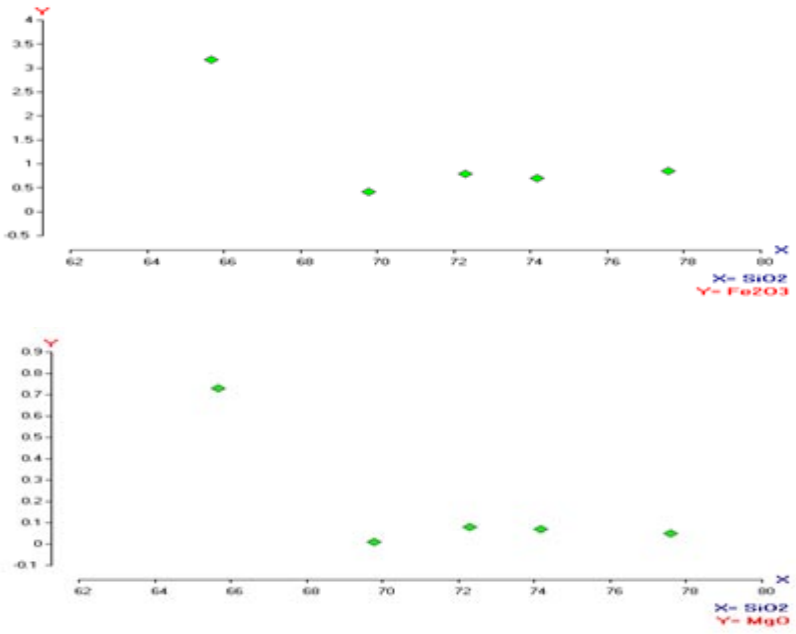


Fig 4b: Harkers diagram for SiO_2 vs K_2O, Fe_2O_3 and MgO

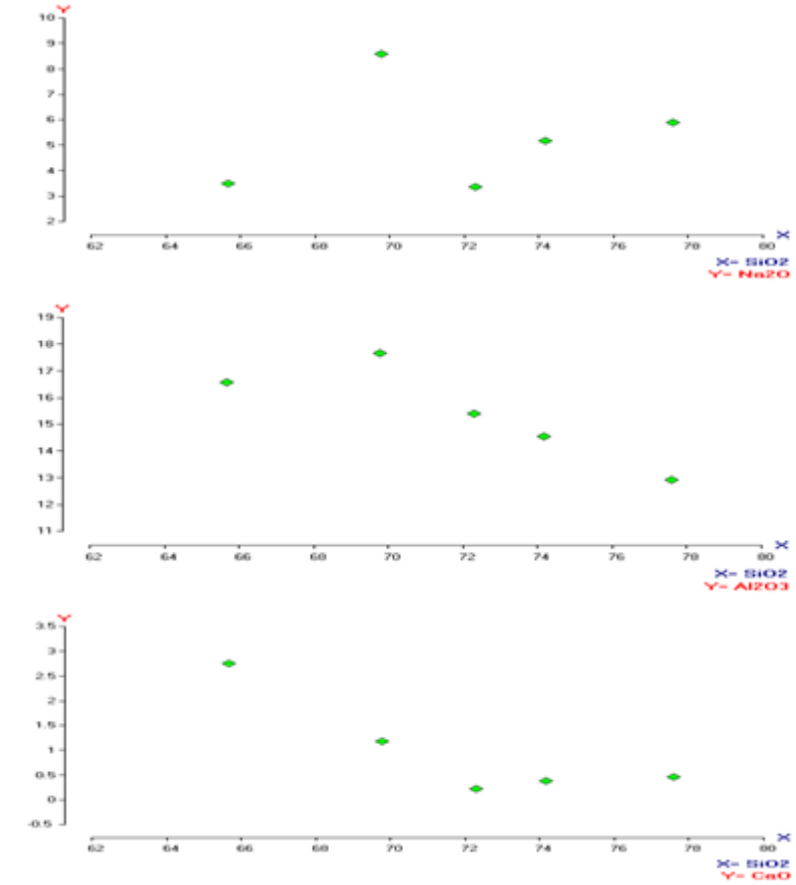
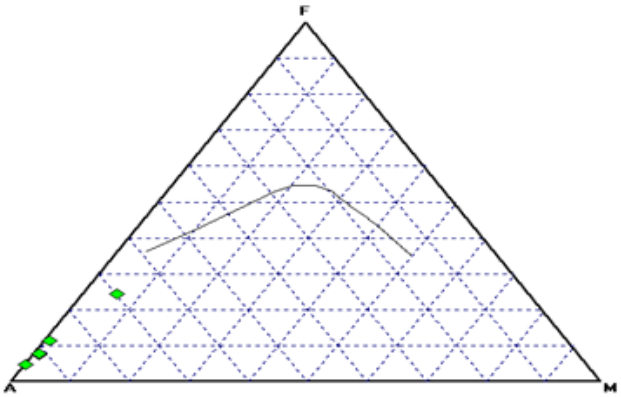
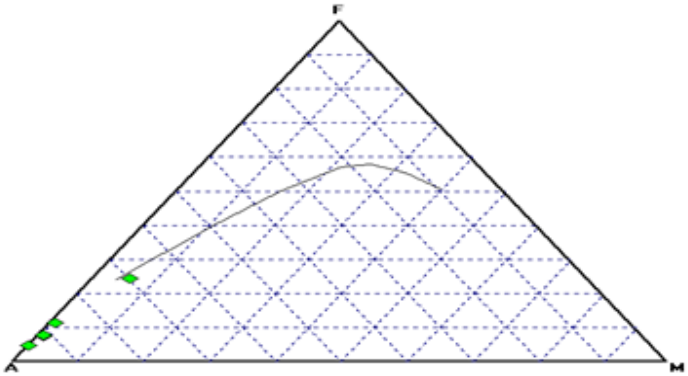


Fig 4c: Harkers diagram for SiO_2 vs Na_2O, Al_2O_3 and CaO

Harker's plot of SiO_2 against P_2O_5 showed negative correlation which implies that as SiO_2 increases, P_2O_5 decreases denotes they are from the same geological environment. The SiO_2 VS TiO_2 Harkers plot also show a negative correlation as SiO2 increases there is decrease in TiO_2 and shows they are from thesame geological environment. So also for Fe_2O_3 and MnO, Al_2O_3, MnO, MgO, CaO also showing the same geological environment. Na_2O shows a positive correlation showing it from a different geological environment



A - Total Aluminum oxides, F-Total Iron oxides, M-Total Magnesium oxides
Fig 5a: AFM plot for Awo rock samples (after Kuno, 1968).



A- Total Aluminum oxides, F- Total Iron oxides, M-Total Magnesium oxides
Fig 5b: AFM plot for Awo pegmatites (after Irvine and Baragar, 1971).

The AFM diagram falls in to the calc- alkaline rock suite. One of the abundant groups of the igneous rocks produced at the continental margin. The term calc-alkaline derives from Peacock (1931) classification of igneous rock group. Chemical analyses of rocks in the series are plotted in terms of F (Total FeO), M (MgO) and A (Alkalis).

Rocks of the study area plot along the Calc-alkaline rock suite: Rocks of the calc alkaline show changes in composition that indicate an increase in magma composition of Alkali and silica, with simultaneous decrease in the total Fe content. This is caused by separation of phases having higher Fe/Mg ratio than the melt. Igneous rock classification based on silica percentage reveals an acidic rock type (greater than 66%).

Economic Geology of the Pegmatite: The pegmatite of the study area contains economic mineral such as quartz, feldspar, muscovite, tourmaline, garnet and beryl. Quartz serves as a raw material in the production of abrasives, refractories, and in the making of glass. Feldspars are used in ceramics and in making of glass. They also serve as a source of alumina and as a partial replacement of soda ash. They are indispensable raw material used for the production of porcelain enamels, flux and filter in latex paints (when finely ground). They are employed in the manufacture of abrasive, cleaners, and polishes. Ground feldspars are extensively used in scouring and cleaning, and as non-skid dusting agent for oil and slippery floors. Muscovites are used as raw material in the manufacture of insulators in the electrical industries. They can also be used in cosmetic industries. Beryl is used as ornamental stone (Inyammah, 2006). Weathered or altered feldspar leads to formation of clay minerals like Kaolinite. Kaolinite is used widely in paint industry, pharmaceutical industry, textile industry for various industrial mineral applications. Silica sand and gravels are used for various building and construction purposes.

CONCLUSION

The pegmatites of the study area constitute a magmatic suite within the Precambrian basement complex of southwestern, Nigeria. It can be concluded that the pegmatite of the study area are associated with various rock types such as syenite, biotite gneiss, migmatite gneiss, porphyritic granite, banded gneiss and quartzite. The pegmatites have mineralogy which consists of microcline, plagioclase, quartz, micas (muscovite and biotite), opaque minerals and other accessory minerals like apatite, zircon, sphene, ilmenite and magnetite. The pegmatites are rich in economic minerals like beryl, tourmaline, tantalite, clay minerals, silica sand and gravel. This is an indication that the pegmatites are of the complex type although simple (barren) pegmatite are noticed in some parts of the study area.

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