GLOBAL JOURNAL OF GEOLOGICAL SCIENCES VOL. 4 NO. 2 2006 : 199 - 207
COPYRIGHT© BACHUDO SCIENCE CO. LTD PRINTED IN NIGERIA. ISSN 1596 - 6798

COMPOSITIONAL FEATURES AND PETROGENETIC AFFINITY OF PRECAMBRAIN AMPHIBOLITIC-SCHIST OF SEPETERI AREA SOUTH WESTERN NIGERIA.

O. A. OKUNOLA, A. I. AKINTOLA and R. O. EGBEYEMI

(Received 19 May, 2005; Revision Accepted 24 September, 2005)

ABSTRACT

Amphibolites, which occur as low lying well foliated, green, fissile schistose rock, are intruded by near flat lying Pegmatites around Sepeteri area Southwestern Nigeria. They are composed of chlorite dominantly and minor amount of hornblende, quartz, biotite, and plagioclase.

Geochemical data obtained using **ICP-MS** analytical method for fifteen samples show average SiO_2 content of 59.27%. While Fe_2O_3 content is 9.35%. MnO (0.19%) and TiO_2 values are less than 1.0%. MgO (11.87%), CaO (9.05%) content are relatively enhanced, while in contrast, Na_2O (0.12%), K_2O (0.26%), and P_2O_5 (0.85%) values are low. Trace element compositional trend shows relatively enhanced average values of Ba (658 ppm), Sr (712ppm) and Zr (170ppm), Cs (46 ppm), Rb (20 ppm), Sn (49 pmm) and Li (68 ppm) are low.

Elemental ratios $Cao/A1_2O_3$ (<0.9); and plots of $Na_2O + K_2O$ versus $100 \times K_2O/(Na_2O + K_2O)$ reveals the igneous ancestry of the amphibolites. Similarity to tholeiitic basalts in some respect is revealed by the plot of Ga-Y, $Na_2O + K_2O$ versus SiO_2, and Ti-Ga-Y discriminant plots. They also have tectonic affinities with Mid Oceanic Ridge basalts (MORB), while few of the schistose samples plot as Within Plate Basalts (WPB).

On the basis of field relationships and overall petrochemical nature and characteristics, the Sepeteri amphibolites are considered to represent ultimately a tholeitic suite emplaced through rifted crustal segment, into an environment of active deposition.

It is considered that later metamorphic, metasomatism and tectonism may have contributed to the alteration of original compositional character and fabric of the parent rocks.

KEYWORDS: Amphibolitic, Schist, Sepeteri, Metamorphism, Metasomatism

INTRODUCTION

The Basement Complex of Nigeria is composed mainly of gneisses and migmatites, which bear the imprint of early late Precambrian metamorphic episodes. Igneous reactivation of this suite which are attributed to the Pan-African (~600ma) are the most pervasive tectonic-fabric event. A number of northerly trending Proterozoic schist belts occur prominently within the western part of the Precambrian basement complex of Nigeria (Fig. 1). They are composed dominantly of pelitic and semi pelitic schists and quartzites. However, within this succession are bodies of amphibolites and ultramafic schists that are exposed mainly in the north west around Maru (Egbuniwe, 1982) Alawa (Truswell and Cope, 1963; Elueze 1985), around Ilesa in the southwest (de Swardt, 1953; Hubbard 1975; Olade and Elueze 1979; Ajayi 1980) Burum (Okunlola, 2001) and Sepeteri (Akintola 2004). Some of the amphibolite occurrences have been described as epichlorites (de Swardt; 1953; Hubbard 1975) metamorphosed calcareous sediments (Oyawoye, 1972) or metamorphosed tholeiitic basalts and peridotitic sills or flows (Olade and Elueze 1979; Elueze 1985; Okonkwo and Winchester 1996; Okunola 2001). The study of the petrochemistry of amphibolites has found in recent years, extensive application in the study of crustal evolution in Precambrian terrains (Graham 1976, Ambrustmacher 1977; Elueze 1980, 1985, Honkamo 1987; Okonkwo and Winchester 1996). This study therefore presents the results of mineralogical and geochemical investigation of the Sepeteri amphibolitic-schist with a view to elucidate their petrographic and chemical character as well as their petrogenetic affinity and tectonic significance.

Regional Geological Setting

The Precambrian basement complex of Nigeria which occurs within the Pan African (Ca 0.6 Ga) province east of the Archean to early proterozoic West African craton (Fig. 1) is subdivided into three principal groups. These are the ancient migmatite-gneiss-quartz complex, the schist belts, and the Pan-African ca. (60 Ga) plutonic series. The migmatite gneiss suites are mainly Ca 2.8 and 2.0 Ga ages. However older ages > Ca 3.0 Ga were recently indicated for the Kaduna migmatite (Dada 1989; Brugurer et al 1994). This reinforces the view that this migmatite gneiss complex may belong to an Archean proto shield subjected to Proterozoic thermotectonic process (Elueze, 1992). The northerly trending Proterozoic schist belts occur prominently within the western part of Nigeria and show distinctive petrologic and structural features. There are numerous belts in the northwest while others in the southwest include Iseyin, Igarra-Okene and Egbe-Isanly schist belts. Occurrences more recently highlighted include the Toto-Gadabuke schist belt, which host the Burum amphibolites (Muotoh et al 1988; Okunlola 2001), Iseyin -Oyan schist belt which host the Sepeteri amphibolites (Rahaman, 1976), and the ones in the southeastern sector of the country (Ekwueme 1987). They are composed largely of metamorphosed pelitic and psammitic assemblages. Secondary lithologies such as ferruginous (banded iron formation) carbonate and mafic-ultramafic bodies are often used in discriminating them. Pan African granites, granodiorites and other calcalkaline intrusive bodies commonly intrude the gneissic assemblages and the lithologies of the schist belt.

Geology of the Study Area

Field Distribution and Petrography

In the Sepeteri Area, (Fig. 2), the amphibolites are associated with pegmatitic rocks. They are well foliated, greenish to dark grey in colour, fissile, fine grained schistose rock occurring as low-lying outcrops localized around the eastern, central and western portion of the study area. They are sometimes layered, and petrographically belong to the schistose variety of amphibolites of Nigeria (Elueze 1985, Okunlola 2001, Elueze and Okunlola 2003).

This section study shows that the rock is made up mineralogically of chlorite, hornblende, plagioclase and quartz. Biotite, olivine, apatite, and zircon are present as accessories. Quartz occurs as small anhedral irregular grains exhibiting wavy extinction. Plagioclase occurs as small subhedral crystals often corroded in some samples. Biotite occur as

O. A. Okunola, Department of Geology, University of Ibadan, Ibadan, Nigeria.
A. I. Akintola, Earth Sciences Department Olabisi Onabanjo University Ago-Iwoye, Nigeria
R. O. Egbeyemi, Department of Geology, University of Ibadan, Ibadan, Nigeria.

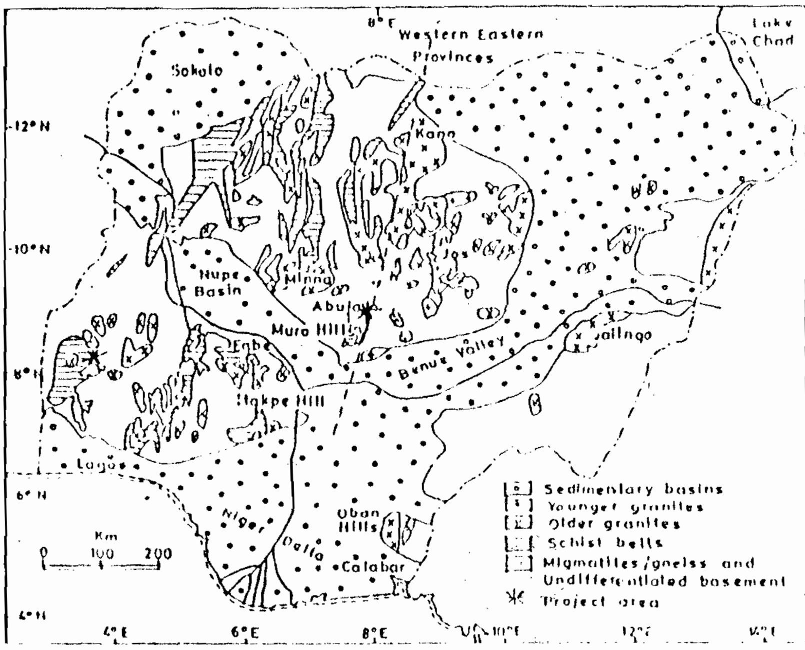

Fig. 1 Outline geological map of Nigeria showing location of project area.

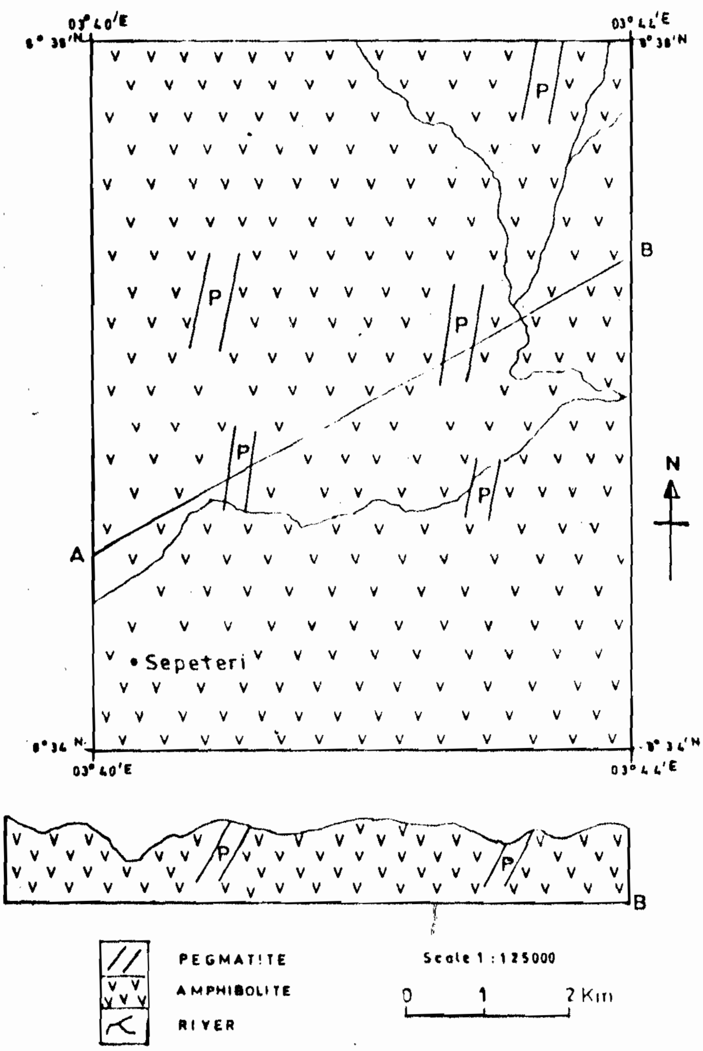

Fig. 2 GEOLOGICAL MAP OF SEPETERI AREA

brownish coloured grain, poikiloblastic within hornblende. Chlorite is greenish in colour, occurring as thinly elongated grains pleochroic from yellowish green to dark green as shown in plate 1^A.

Geochemical Character of the Amphibolites

Analytical Methods

Determination of major and trace element concentrations was at the Activation Laboratories limited in Canada, using 1CP-AES Instrumentation method. A sample weight of 0.5g and about 75 micron was put in the platinum crucible. 5ml perchloric acid, HNO_3 and 15ml hydrofluoric acid were added. The solution was stirred properly and allowed to evaporate to dryness after it was warmed at a low temperature for some hours. 4ml hydrochloric acid was then added to the cooled solution and warmed to dissolve the salts. On cooling, the solution was diluted to 50ml with distilled water. This was then introduced into the ICP torch as aqueous aerosol. The emitted light by the ions in the ICP was converted to an electrical signal by a photo multiplier in the spectrometer. The intensity of the electrical signal produced by emitted light from the ions were compared to a standard (a previously measured intensity of a known concentration of the elements) and the concentration then computed.

The chemical data of the representative samples are shown in (Table 1)

PLATE 1^A
Photomicrograph of Sepeteri amphibolites in transmitted light showing Quartz (q), hornblende (h), plagioclase (p) Biotite (b) with apatite occurring as accessory mineral

Bar Scale 2mm

Results and Interpretation of Major, Trace Elements and Elements Ratio

The Sepeteri amphibolite which is of the schistose variety, has *mean SiO_2 value of 59.27% with a value range of* (58.43-59.92%), these values are similar to those of schistose Burum amphibolites (Okunlola and Elueze, 2003); Alawa amphibolites (Elueze 1985) and the Ife-Ilesha amphibolites (Ajayi 1980). However, average $A1_2O_3$ values of 7.95% are lower than that of Holleindan amphibolite (Elliot and Cowan, 1966). Burum amphibolite (Okunlola and Elueze 2003) but higher than that of Ilesha Talc Tremolite schist (Olade and Elueze 1979). It is also comparable to that of the Archean metabasalt of Superior Province Canada (Gilkson, 1997) The relatively high SiO_2 values may have been due to late metasomatic crustal contamination from latter Pan African events involving intrusion of siliceous pegmatites into the amphibolites. This is similar to observation by Dada (1989) for some Precambrian amphibolites of Nigeria.

Similarly, average Na_2O content is 0.12% while average K_2O content in Sepeteri amphibolites sample is less than 0.65%, this is similar to value for the Idanre amphibolites (Ocan, 1990) and oceanic tholeiites and primitive rocks (Gilkson, 1977). Conversely however, the schistose of Sepeteri amphibolite have total Fe_2O_3 mean value of 9.35% compared to 10.35% of Burum Amphibolite (Okunlola and Elueze 2003). The comparatively lower Fe_2O_3 values in the former may be due to the reduced amount of the melanocractic minerals. A similar trend is noticed for the TiO_2 concentration where average values of 0.82% for the schistose amphibolite of Sepeteri are relatively higher than those of the Burum amphibolite (Okunlola, 2001) but comparable to that of Alawa amphibolite (Elueze, 1985).

The same compositional trend is noted also for the MgO values, which ranges between 9.73% and 12.64% and when compared with that of Alawa amphibolite have a greater concentration. These Fe_2O_3, MgO, TiO_2 contents of the amphibolites are comparable to the Hollendane metabasite (Elliot and Cowan, 1966) but higher than Ilesha Amphibolite (Olade and Elueze, 1979).

Trace element composition reveals that Sr concentrations are higher (712ppm) in the Sepeteri Schistose amphibolite compared to the banded (54ppm) and massive (45ppm) amphibolite of Burum. (Okunlola, 2001). Similarly, Rb (20.98ppm), Ni (66.8ppm) and Ba (658.5ppm) concentration are higher in the Sepeteri amphibolite than the banded and the massive varieties of Burum amphibolite (Elueze and Okunlola, 2003). These compositional characters are comparable to Archean metabasalts and oceanic Tholeiites (Gilkson, 1997) and Idanre tholleitic amphibolites (Ocan, 1990). Also, average Cr value for the Sepeteri schistose variety (137.5ppm) are greater than that of Burum amphibolite (15ppm) and lower than that of Ilesha schist (211 1ppm) (Elueze, 1981). These values are comparable to the west Australian Archean metabasalt (Hallberg, 1977) but lower than Average Alawa laminated amphibolites (Elueze, 1985) and Ilesha amphibolitic schist (Elueze, 1981).

Ti, Zr, Y, Co and Ga concentrations which have been used by Floyd and Winchester (1978) and Pearce and Cann (1973) to indicate petrogenetic character and tectonic setting of altered mafic rocks has also been used in the case of the Sepeteri amphibolites. Average Co (10.4ppm) in the Sepeteri amphibolite is lower than that of the Burum amphibolite (17ppm). Zr is 170.83ppm, Y values is also 51.2ppm; while Ga ranges between 5.21-8ppm. These values are comparable to that of tholeiitic rocks (Floyd and Winchester, 1978) and subalkaline basalt and Tholeiites (Kogarko, 1973). Low Cao/Al2O3 ratio (<0.9) for the amphibolite sample suggests igneous parentage (van de kamp 1968). Average K/Rb value

TABLE 1:
Analytical Results Of Sepeteri Amphibolites

Major elements (%)	Average(n = 10)	Range
SiO_2	59.27	58.43 – 59.92
TiO_2	0.82	0.71 – 1.20
AL_2O_3	7.95	4.78 – 9.43
Fe_2O_3	9.35	8.01 – 10.35
MnO	0.19	0.31 – 0.27
MgO	11.87	9.73 – 12.64
CaO	9.05	8.01 – 10.13
Na_2O	0.12	0.01 – 0.202
K_2O	0.26	0.06 – 0.38
P_2O_5	0.85	0.22 – 3.758
Total	99.73	
TRACE ELEMENT PPM		
Ta	24.12	4.2 – 83.0
Cs	46.18	29.5 – 59.6
Rb	20.98	14.9 – 26
Sn	49.47	34.14 – 85.7
Nb	23.62	4.41 – 46.12
Li	68.55	34.7 – 174.0
Sr	712.5	395 – 790
Y	51.2	23 – 28
Ba	658.5	81 – 790
W	1.78	1.3 – 3.2
Be	8.83	2 – 23
Zr	170.83	171 – 175
Ga	6.20	5.21 – 8
Cr	137.5	105 – 175
Co	10.4	7.1 – 14.2

for the schistose 0.011ppm is lower than that of Archean basaltic series (Jahn et al 1974). Rb/Sr ratio is generally less than 0.03 and comparable to the Ilesha amphibolites (Olade and Elueze, 1979) and Jebba amphibolite (Okonkwo and Winchester, 1996). Samples of the amphibolite plotted on the K_2O-TiO_2-P_2O_5 diagram (Pearce et al 1975) (Fig 3) shows them plotting within the continental basalt field. While sample plotted on the $Na_2O + K_2O$ versus $100 \times K_2O$ ($Na_2O + K_2O$) suggest their igneous origin. (Honkam 1987) (Fig. 4) On the Na_2 + K_2O versus SiO_2 plot, the amphibolite plot as tholeiitic basalt (Irvine and Barager, 1971) (Fig. 5) Discriminant diagrams using Ti-Ga-Y plot (Fig. 6) provide further clearer pictures of the petrogenetic affinities of the amphibolite. Also similarity to tholeiitic basalt in some respect is revealed by plots of $Na_2O + K_2O$ versus SiO_2 (Fig. 5). Ti-Ga-Y (Fig 6), Ga-Y (Fig 7) and $Na_2O+K_2O+Fe_2O_3+MgO$ (Fig 8) suggests their tholeiitic character. Samples plotted on the Ga-Y diagram (Fig. 7) show majority of the samples plotting below 1 ratio, which is also an evidence of tholeiitic affinity (Elueze 1985, Honkamo, 1987). When plotted on an AFM diagram (Fig 8) the samples plot within the tholeiitic series on the Zr/Y versus Zr diagram of Pearce and Norry 1979, (Fig. 9) most of the samples plot in the Mid Oceanic Ridge Basalt (MORB) Field. This shows and suggests that the Sepeteri amphibolites have tectonic affinities with Mid Oceanic Ridge Basalt (MORB). Although some of the schistose sample also plot as within plate Basalt (W.P.B). This tectonic feature is similar to that of Jebba amphibolites (Okonkwo and Winchester, 1966) Ile-Ilesha amphibolites (Rahaman et al. 1988) and Burum Amphibolites (Okunlola and Elueze, 2003).

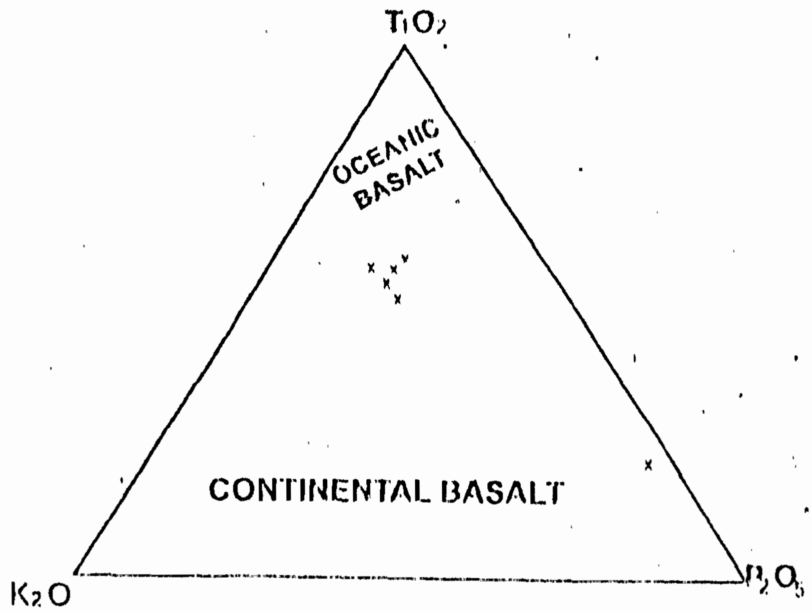

Fig 3: Plot of Sepeteri Amphibolitic Schist on K_2O - TiO_2 - P_2O_5 diagram (after Pearce et al 1975)

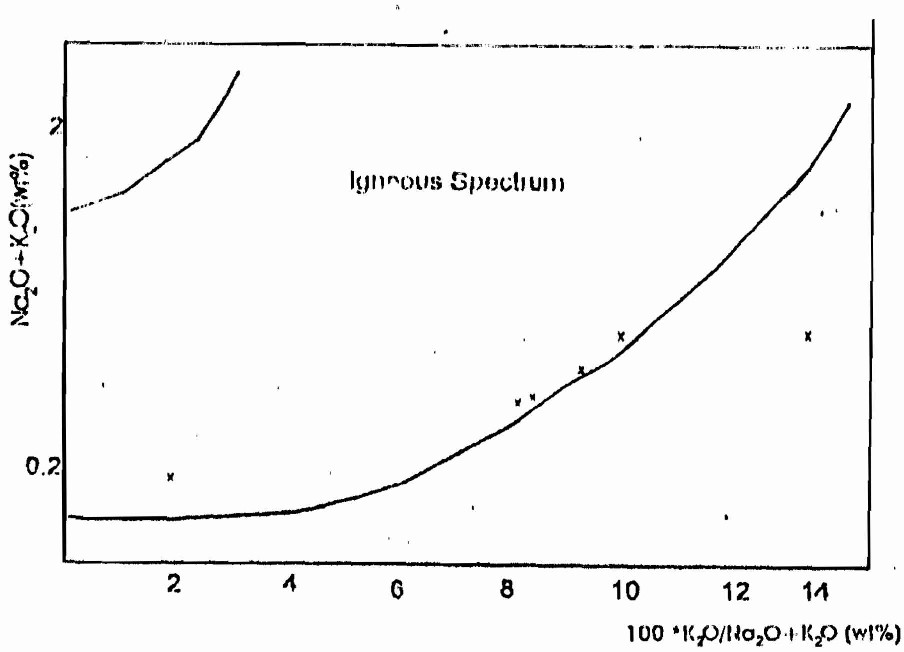

Fig 4: Na_2O+K_2O Vs 100 *K_2O/Na_2O+K_2O (wt%) diagram for Sepeteri Amphibolite (After Hughes modified by Honkamo, 1987)

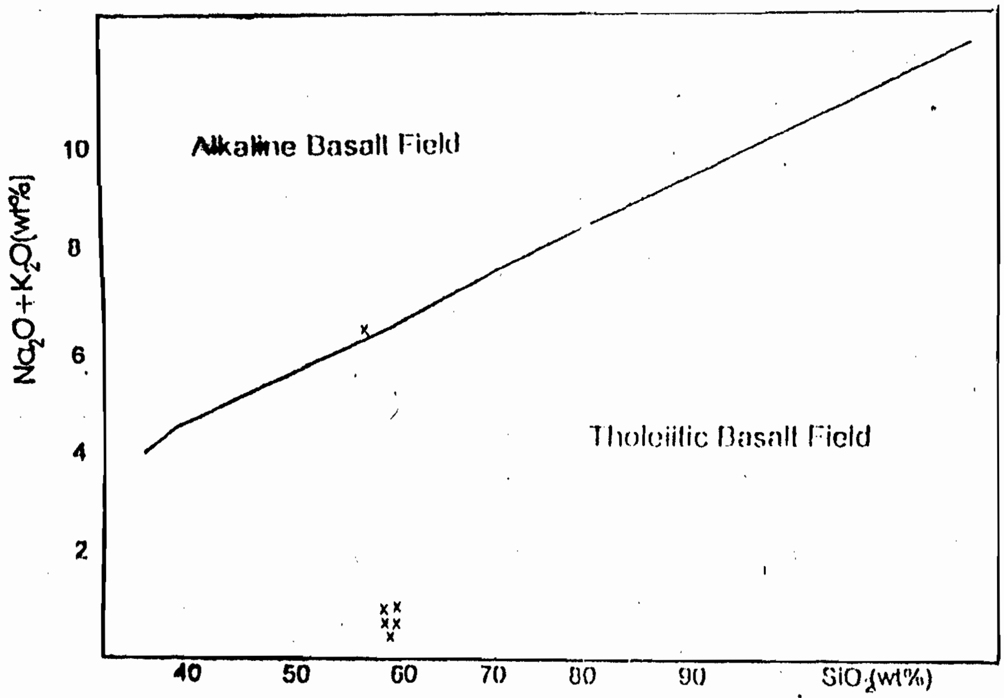

Fig 5: Alkaline - Silica diagram for Sepeleri Amphibolite (Irvine and Barager, 1971)

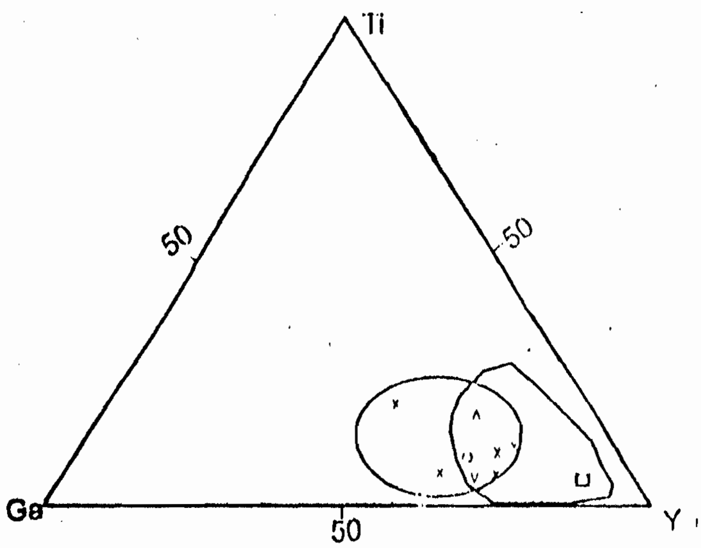

Fig 6: Ti - Ga - Y plot for: Sepeleri amphibolitic schist compared with) other basaltic rocks

X - Sepeleri Samples (undifferentiated)
o - Alawa tholeiites (Elueze 1985)
^ - Tholeiitic Basalt (Manson, 1967)
□ - Bighorn Tholeiites (Ambiustmacher 1977

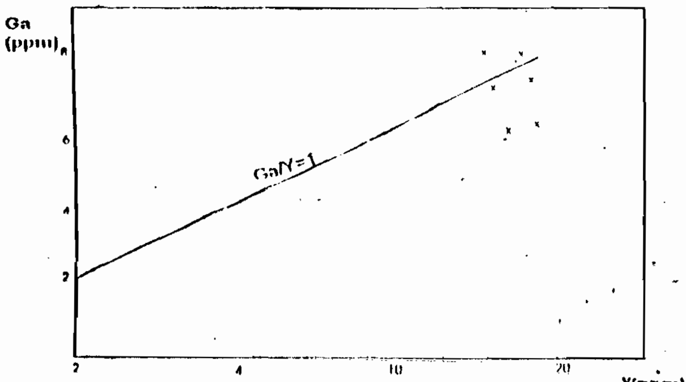

Fig 7: Ga-Y plot for amphibolite of Sepeteri area (cox et al, 1967)

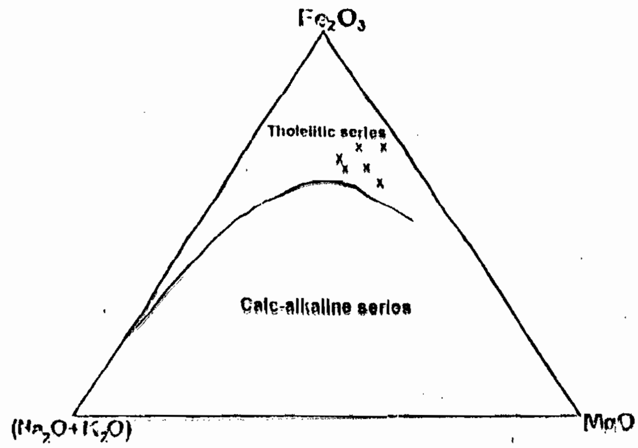

Fig 8: AFM diagram for the amphibolites from Sepeteri (Irvine and Barager, 1971)

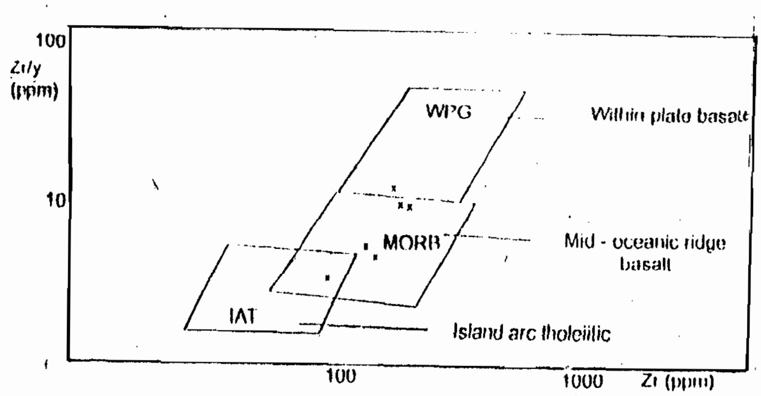

Fig 9: Zr/Y - Zr diagram for Sepeteri Amphibolite (After Pearce and Norry, 1979)

CONCLUSION

Petrographic and chemical character evaluation of the Sepeteri amphibolite reveal one textural distinction, which has a bearing on the overall petrochemical features. However, it should be noted that despite the textual and chemical distinction, acquired data show that they are mafic volcanics emplaced in a domain of active sedimentation. Chemical indices such as Y, Ga values and Ni/CO ratios reinforce this assertion that they are derivatives of tholeiitic basalts. Although there does not seems to be general agreement concerning the geodynamic evolution of the Nigeria schist belts, evidence of a largely ensialic terrain has been provided (Olade and Elueze 1979; Elueze 1985). This implying that these mafic series may have been emplaced in a continental environment. Nessbit; (1980) has suggested that such genetic character agrees with a model of evolution involving initial continental rifting preceding generation of "primitive" magmas from deep crustal sources. In view of this, the Sepeteri basaltic rocks may have evolved from a deep crustal source through channels initiated by the rifted crustal segment. This was accompanied by sedimentation within the fault-bounded rift developed due to subsidence along the fracture boundaries. The mineralogical and textural fabric and composition of this schistose rocks are probably products of subsequent metamorphic episodes.

ACKNOWLEDGEMENTS

The authors are highly indebted to Prof. O.O. Kehinde Phillips, Prof. S.S. Dada, and Dr. A.F. Abimbola and Mr. Olaifa for considerable support. Numerous colleagues and friends who contributed in various ways are also acknowledge. Chemical analysis was executed at the Activation laboratories Canada; Dr. O. Oshin was exceptionally supportive.

REFERENCES

Ajayi, T.R., 1980. Geochemistry and origin of the Amphibolites of Ife-Ilesha Area S.W. Nigeria. Nigerian J. Min. Geol. 17: 179-195.

Akintola, A.I., 2004. Petrography and Petrogenetic features of the rare metal pegmatite and associated amphibolitic schist of Sepeteri area south western Nigeria. Unpubl. M.Sc Thesis, University of Ibadan.

Ambrustmacher, T., 1979. Geochemistry of Precambrian mafic dikes; central Big horn mountain Wyoming. USA Precambrian Re, 4:13-38.

Cox X.G.; Mac Donald R. and Hornug G., 1967. Geochemical and petrographic province in the karroo basalt of Southern Afra; Am. Mineral. Earth planet. Sc. Let 24, 419-426.

Dada, S.S. and Briqueu L., 1996. Pb-Pb and Sm-Nd Isotopic study of metal igneous rocks of Kaduna: implications for the Archean mantle in Northern Nigeria, 32nd Annu. Conf. Nigeria Min. Geosc. Soc; Benin City. Abstr. 57p.

De Swardt A.M.J., 1953. The Geology of the country around Ilesha. Geological Survey of Nigeria, No. 23, pp 1-49.

Egbuniwe, I., 1982. Geotectonic evolution of Maru Belt. NW Nigeria. Unpublished Ph.D. Thesis, University College of Wales Aberysth 400p.

Ekwueme, B.N., 1987. Structural orientations and Precambrian deformational episode of Uwet Area. Oban Massif S.E. Nigeria Precambrian res; 34 pp. 269-289.

Elliot, R.D., and Cowan, D.R. 1966. The petrochemistry of the amphibolites of the Holeindain green stone group. John Beimen, Norwary. Norsk Geol. Tidsskr 45, pp 309-325.

Elueze, A.A., 1985. Petrochemical and petrogenetic characteristic of Precambrian Amphibolites of the Alawa District: North West Nigeria. J. Chemical Geology 48, 29-41.

Elueze, A.A.,1980. Geochemical studies of Proterozoic amphibolites and metaultramafites in Nigeria schist belts; implication for Precambrian crustal evolution PhD Thesis University of Ibadan, Ibadan (unpublished).

Elueze, A.A., 1992 Rift system of Proterozoic schist belts in Nigeria tectonophysics, 209, pp. 167-169.

Elueze, A.A., 1981. Geochemistry and petrotectonic setting of metal sedimentary rocks of the schist belt of Ilesha area southwestern Nigeria. Precambrian research, pp. 303-318.

Elueze A.A. and Okunlola O.A., 2003. Geochemical features and petrogenetic affinity of Precambrian amphibolites of Burum area central Nigeria.

Floyd, P.A. and Winchester, J.A., 1978. Magma type and tectonic setting, discrimination using immobile elements Earth planets sci. lett; 27: 221-218.

Gilkson, A.Y., 1977. Primitive Archean element distribution patterns: chemical evidence and geotectonic significance. Earth planet. Sci Lett. 12: 309-320.

Graham, C.M., 1976. Petrochemistry and Tectonic significance of Daldrian metabasaltic rocks Scottish high lands. J. Goel. Soc. Lond, 132: pp 61-84.

Hallberg. J.A., 1972. Geochemistry of Archean volcanic belts in the Eastern Goldfields regions of western Australia J. Petrol 13:45-56.

Honkamo, M., 1987. Geochemistry and Tectonic setting of early Proterozoic volcanic rocks in Northern Osthuthotria Finland in pharaoh T.C., Beck Sale R.D. and D. Rick hard eds. Geochemistry and mineralization of Proterozoic volcanic suites Geol. Soc. Spec. publ. No. 38.

Hubbard, F.H., 1975. Precambrian crustal development in western Nigeria. indication from the Iwo region. Geol. Soc. Am. Bull, 86, pp. 548-554.

Irvine, T.N. and Barager W.R.A., 1971. A guide to the classification of common volcanic rocks can. J. Earth sci. 8, pp. 523-548.

Jahn B. Shih. C. Murthy V.R., 1974. Trace element geochemistry of Archean volcanic rocks Geochem Cosmochim. Acta. 38: 611-622.

Kogarko, L.M. 1973. The Ni/Co ratios as an indicator of mantle origin of magmas. Geochem, int. 10 (5): 1081-1086.

Moutoh, E.O., Oluyide P.O., Okoro A.U. and Mogbo O. 1988 The muro hills banded iron formation, in P.O. Oluyide, W.C. Mbonu, A.E. Ogezi, I.G. Egbuniwe, A.C. Ajibade and A.C. Umeji (eds) Precambrian Geology of Nigeria, Geological survey of Nigeria Kaduna, pp. 219-227.

Nessbit, R.W., 1980 Komatiites an early Precambrian phenomenon. 26 int. Geol Congr Paris, Abstr, 1 68-69.

Ocan, O.O., 1990. The petrology of rocks around Idanre Area, southwestern Nigeria unpublished PhD Thesis Obafemi Awolowo University, Ile-Ife, pp. 6-12.

Okonkwo, C.T. and Winchester, J.A., 1996. Geochemistry and geotectonic setting of Precambrian Amphibolites and Granitic Gneisses in the Jebba area southwestern Nigeria J. of min and Geol Vol. 32, 1996, No. 1, pp 11-18.

Okunlola, O.A 2001. Geological and compositional investigation of Precambrian marble bodies and associated rocks in the Burum and Jakura area. Nigeria Unpublished Ph.D. Thesis University of Ibadan.

Olade and Elueze, 1979. Petrochemistry of the Ilesha amphibolites and Precambrian crustal evolution in the pan-African domain of S.W. Nigeria Precambrian Research, 8: 303-313.

Oyawoye, M.O. 1972. The basement complex of Nigeria in Dessauwagie T.F.J. and Whiteman A.J. eds Africa Geology.

Pearce, J.A. and Cann J.R. 1973. Tectonic setting of basic volcanic rocks determined using trace element analyses, Earth planet, sc., Lett. 19: 290-300.

Pearce, J.A. and Norry, M.J. 1979 Petrogenetic implication of Ti, Zr, Y, and alb, variation in volcanic rock contribu Min petrol 69, pp 33-47.

Pearce, T.H., Gorman B.E. and Bir Kett T.C. 1975. The TiO_2-K_2O-P_2O diagram, a method of discriminating between oceanic and non oceanic basalts.

M.A. 1976. Review of the basement Geology of southwestern Nigeria in Geology of Nigeria edited by C.A. Kogbe, Elizabeth publishing Co., Lagos, pp. 41-58.

Truswell, J.F. and Cope R.N. 1963. Tahe geology of parts of Niger and Zaria provinces, Northern Nigeria Geol Surv Niger Bul No. 29, p. 41