Migmatite and Gneisses in the Basement Complex of Southwestern Nigeria: a re-appraisal of their structural, mineralogical, and geochemical diversity

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Abstract:
The structural, mineralogical and petrochemical diversity of migmatite-gneiss in the Basement complex of Southwestern Nigeria were re-appraised. The study of these country rocks exhibited structural heterogeneities that classified them into migmatite, banded gneiss and granite gneiss sub-groups. The units are typically hypidiomorphic to porphyroblastic with varying degrees of structural complexities. The variably deformed rocks have dominant N-S and NNE-SSW trending foliations and lineaments. These typically low-lying rocks are leucocratic to melanocratic and contain varying proportions of felsic-mafic components. Mineralogical composition shows dominance of quartz, feldspars, biotite, hornblende, and muscovite while opaque and pyroxene occur in subordinate amounts. Analytical results indicate that the rocks show cryptic but systematic variation in major elements distribution. The average mean SiO_2 contents in Idanre migmatite (65.00 %), Ita-Ogbolu banded gneiss (62.53 %) and Ado-Ekiti granite gneiss (61.01 %) are suggestive of siliceous class while their average alkali (Na_2O+K_2O) contents showed 6.49 %, 9.23 %, and 8.52 % respectively. Variation plots of Na_2O/Al_2O_3 versus K_2O/Al_2O_3 indicate that the rocks have igneous parentage, Al_2O_3 versus MgO classifies the rocks as orthogneiss, K_2O versus SiO_2 diagram classifies them as continental granophyre. Trace element composition show lithophile elements (Ba, Rb, Sr, Zr and Ce) enrichment. Geochemical plot of Na_2O/Al_2O_3 versus K_2O/Al_2O_3 revealed these gneisses are products of anatexis of igneous protolith.

Keywords: Migmatites, gneiss , siliceous, orthogneiss, igneous protolith.

INTRODUCTION

Migmatite-gneiss forms one of the three major rock units in the basement complex of Nigeria. However, opinions are diverse regarding the origin of these rocks. Unlike the schist belts, granites and pegmatites which are frequently reported, information on Nigeria migmatite-gneiss is relatively scanty probably because of its structural complexity, polycyclic nature, and nontangible economic mineralization.Migmatite-gneiss form the most widespread rock type in the basement (Ogezi, 1988), covering about 50% of the Nigeria Precambrian domain (Ajibade et al., 1988) and approximately three tenth of the total surface area of Nigeria (Rahaman, 1988). Even though migmatite forms an integral part of the basement complex of Nigeria, its origin has generated much debate among scholars, some authors believed it is of sedimentary origin while others believed it is igneous. Studies on Ibadan granite gneiss by Grant (1970) presented it asigneous origin

while Freeth (1971); Burke and Dewey, (1972), believed they were derived from isochemical metamorphism of shale greywacke. Elueze(1982) supports sedimentary origin for the Ilesha granite gneiss. However, Onyeagocha (1984) proposed igneous origin by partial melting of crustal rocks for the granite gneiss of north-central Nigeria. Other supporters of the igneous origin include Ekwere and Ekwueme (1991) and Imeokparia and Emofurieta (1991). Bolarinwa, (2004) reported that granite-gneiss from Abeokuta area has igneous parentage but with minor sedimentary input. Rahaman (1988) believed that the available geochemical data were insufficient to equivocally distinguish the granite gneiss as either sedimentary or igneous gneisses. Current view attributes the difficulty of establishing petrogenetic synopsis of these rocks to different rocks being lumped together under the general heading migmatite-gneiss complex Nigeriabasement comprises heterogenous assemblages of migmatite and gneiss-looking rocks. These include ptygmatic migmatite, migmatitic orthogneisses and para-gneisses with nebulitic,magmatitic, dictyonitic structures. Others are granite-gneiss, eugen gneiss, banded gneiss, grey gneiss, biotite gneiss, garnet gneiss, biotite-hornblende gneiss and calc gneiss which exhibit various kinds of structures and origin. Hockey et al., (1986) pointed that distinguishing these migmatite-gneissic rocks which have graded into one another in the field has resulted in attendant and persistent difficulties in describing the migmatite-gneisss throughout the entire basement of Nigeria. Another major challenge as noted by Dietrich and Mehnert, (1961) is that they are described by terminologies having inconsistent nomenclature. Oluyide and others (1998); Dada, (2006) believed the Pan-African tectono-thermal event had homogenized all basement rocks while the combined effects of metasomatism, dynamic metamorphism, migmatization and magmatism produced the various rock types based on their original compositions. Migmatite-gneiss underlies several localities in Southwestern Nigeria. Migmatite-gneisses from three such localities were investigated in the current study with the aim of evaluating their structural, mineralogical, and petrochemical features that may be related to their original.

Regional geology and lithologic associations

The basement complex of Nigeria forms part of the Pan-African mobile belt (Ferré, et al., 2002; Adetunji and et al.2016). Precisely, it lies between West African craton to the west, the East Saharan block to the northeast and the Congo craton to the southeast (Arthaud et al., 2003; Ferré et al.,1996; Dada, 2008) (Fig. 1).

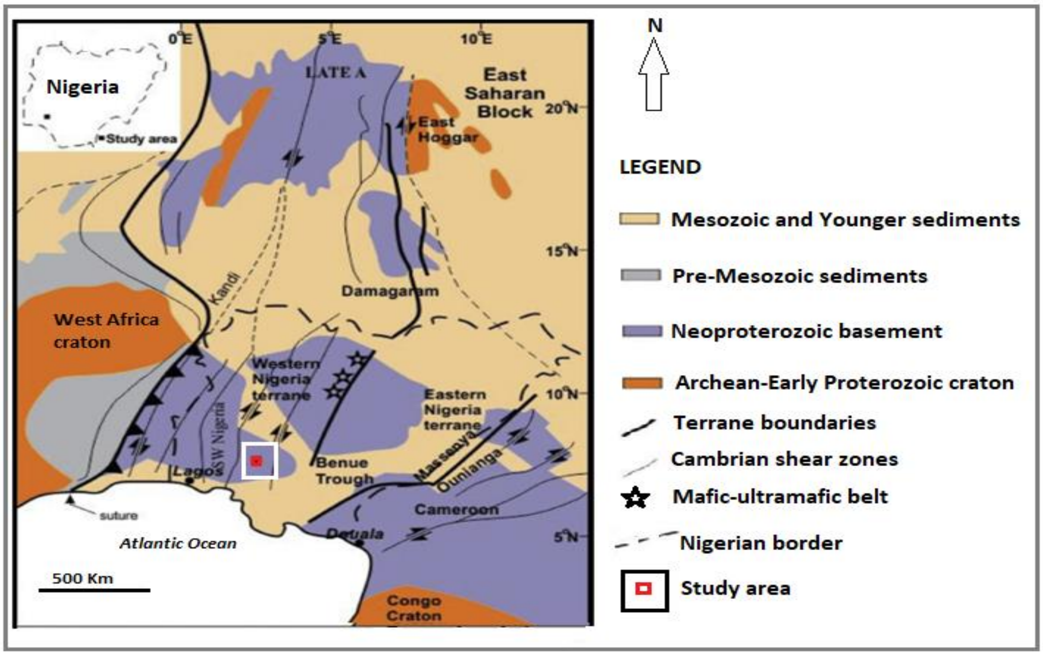

Fig. 1: Geological map of Pan African mobile belt showing Nigeria on the eastern side of West African craton and NW of Congo craton (modified from Ferré et al., 1996; Adetunji et al., 2016).

The Nigeria basement had been affected by major orogenic events of the Liberian (2,700 ± 200 Ma) through Pan-African (600 ± 150 Ma) (Van Breemen and others, 1977, Fitches and others, 1985). Rocks in this domain are loosely categorized into aggregated complex of migmatite-gneiss, schist belts and the Pan-African granite (Fig.2).

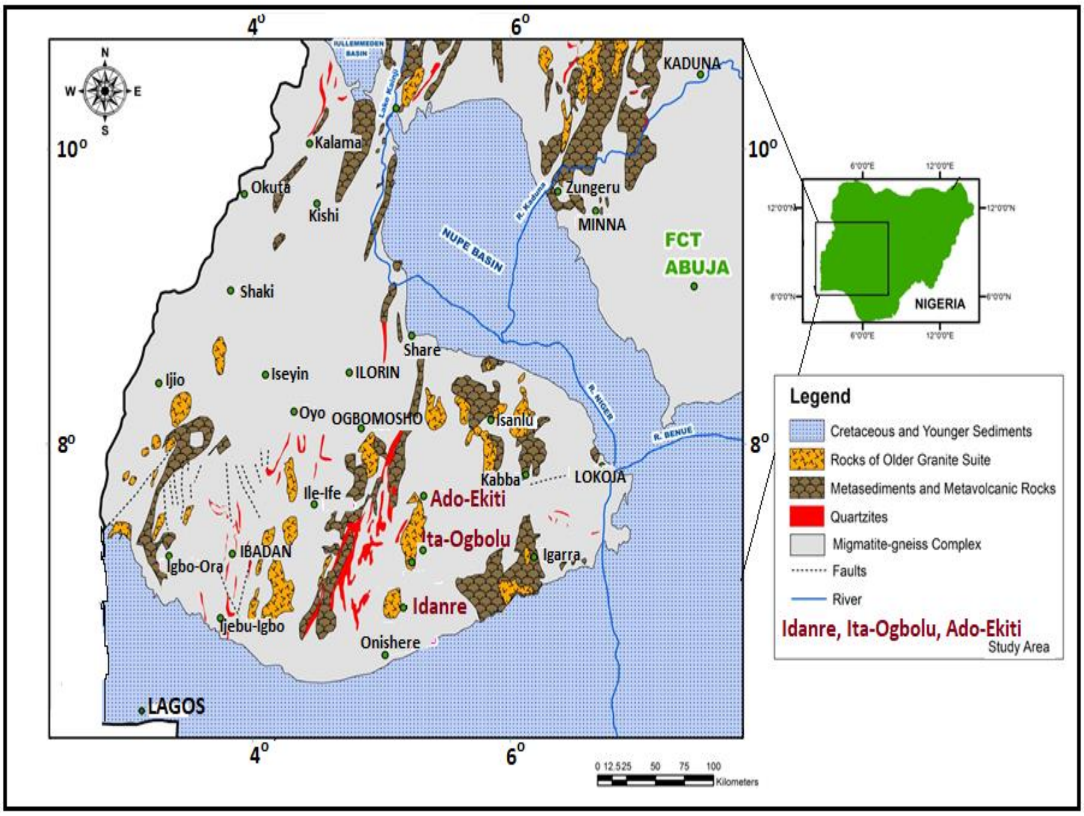

Fig. 2: Geological map of southwestern Nigeria showing Idanre, Ita-Ogbolu and Ado-Ekiti area

These older units were intruded by un-metamorphosed minor acid rocks like aplite, pegmatite, and basic rocks like dolerite (Dada, 2006). Migmatite complex is the oldest unit in the basement, it is tectono-stratigraphically basal to all lithologies and orogenic events (Anifowose and Kolawole, 2012). The unit is dominated by heterogenous assemblage of migmatites, gneisses and granite-gneisses(Obaje, 2009) that exhibit complex deformation styles attributed to its polycyclic nature. The gneissic complex is regarded as the most widespread unit (Udensi et al., 1986; Ogezi,1988) and forms the country rock in most areas underlain by the basement complex. This unit occurs as denuded low-lying masses. Structurally, migmatite basement in most parts is made of several subunits. In some areas, compositional banding is so prominent to be called a banded gneiss. In others, the bands are indiscernible, leaving behind only relics of indistinctly foliated masses that resemble granite-gneiss. Typically, migmatite is a fine-medium grained granoblastic rock with variable structural elements.Tortuous veins which symbolize high-grade regional metamorphism and tectonic deformation are commonly seen on many outcrops while some contains ptygmatic folds. In Idanre area, migmatite forms the country rock which is convoluted into ripples of complex bands containing pods of melanosome intermixed with palaeosome (Fig.3a). The basement gneiss in Ita-Ogbolu form low lying units with many outcrop exposures along a river channel. Some of the rocks are banded and show perfect alternation of light and dark minerals (Fig.3b), in the eastern part, however, the rocks show thin lamination while towards the north, bold mineralogical banding is common. Gneissic outcrops within Ado-Ekiti occupy low depressions adjoining prominent granite masses. It is so common that most areas do not show good rock exposures as they are underlain by granite-gneiss.

Fig. 3: Structural differences in basement migmatite-gneiss units in the study area (a) outcrop of Idanre migmatite gneiss showing clear distinction between the melanosome (dark) and leucosome (light), (b) a low-lying outcrop of banded gneiss exposed at Ita-Ogbolu, (c) an outcrop of granite-gneiss in Ado-Ekiti showing poorly defined foliation, (d) a weathered surface of granite gneiss in Ado-Ekiti.

Apart from having bands not so conspicuous, freshly exposed sample exhibits a greyish outlook due to abundance of felsic mineral contents (Fig.3c).Weathered surface often presents a darker outlook owing to colour alteration (Fig.3d). Structural elements in the gneissic rocks include fractures, joints, quartz veins intrusions and veinlets.

MATERIALS AND METHODS

Samples: Systematic geological mapping of ground trotting using a pair of Silva compass clinometer and a hand-held global positioning system GPS (GERMIN GPS Map 76 CSX) methodological approach were adopted. Twelve fresh whole-rock samples (comprising 4 migmatite, 4 banded-gneiss and 4 granite-gneiss) were collected for geochemical analysis, while six samples (two (2) from each rock type) were used for petrographic investigation. The fieldwork and sampling were carried out during the dry season for greater accessibility. Fresh samples were obtained from outcrop exposures using a sledgehammer and Makute hammer drill. The study area being in a tropical environment characterized by high intensity of weathering, some outcrops were not good enough for sampling and they were therefore avoided. To ensure that only fresh and wholesome samples were obtained, random sampling was adopted as well.

Optical microscopy: Samples were cut into thin sections and ground down using Logitec (Model F) lapping machine and the resulting slides were observed on LEICA *DM*LP polarizing microscope. Modal analysis was determined by estimation.

Geochemical Analysis

Major elements composition was determined using glass fusion discs. Each disc was prepared by adding approximately 0.62 g of rock powder that passed through 153 microns sieve into 3.3 g of lithium borate flux. The mixture was heated at 1000^{o}C and the molten paste is cast into 4cm diameter aluminium platters. The resultant glass disc was then mounted on a baking disc for analysis. Major elements analysis was done using X-ray fluorescence (XRF) geochemical method on Philips PW 1404/10 at the laboratory of Bureau Veritas, Vancouver, Canada. The results showed the following major oxides namely: S_IO_2, AL_2O_3, Fe_2O_3, CaO, MgO, K2O, MgO, MgO, MnO, Na_2O, TiO_2 and LOI. Trace and REE earth elements concentration were determined in the same laboratory using the inductively coupled plasma-mass spectrometry (ICP-MS) method. Analytical precision is 5% at the ppm level. Details of ICP-MS and operating conditions have been published by Norman and others, (1996) and Norman (1998). The results of the analyses are reported in trace and rare earth elements. (Table 3).

Petrography: Optical studies revealed the migmatite-gneiss units are medium to fine grained. The main mineral assemblage include quartz, K-feldspar, plagioclase, biotite, hornblende and opaque. The gneissic subunits have similar mineralogic features, but the different mineral phases occur in varying proportions. The result of petrographic analysis is presented in Table 1.

Idanre Migmatite: Idanre migmatite-gneiss is a medium to fine-grained rock. Under hand specimen examination the weakly foliated rock contains melanocratic and leucocratic minerals in almost equal proportions. Petrographic investigation indicates that biotite, hornblende and opaque minerals constitute the mafic aggregates while quartz and feldspar dominate the felsic assemblage. Quartz contents ranges from 42 to 47%, feldspar (22-28%), hornblende (6-9%), biotite (7-13%), muscovite (6-8%) while opaque varies between 5 and 7% of the rocks mass (table 1). Biotite occurs in greenish, deep brown and pink colours and occurs as mineral laths with high aspect ratios. Sometimes larger plates measure up to 5mm long and 0.4mm in width. Biotite laths are aligned and stretched along same direction. Hornblende is prismatic with attendant acicular habits. The opaque has characteristic black colour and are dominated by magnetite. Quartz porphyroblasts are euhedral to subhedral and are clear with no fuzzy cores or fractures and are well blended into interlocking assemblage of other minerals (Fig.4a). Quartz crystals appear as colourless and clear grains lacking any form of cleavages and constituting approximately 45% of the rock volume. It shows first order polarization colours ranging between grey and white. Feldspar shows faint albite twinning, and some crystals exhibit distorted twin laminae. Tiny plates of biotite and muscovite define the weak foliation as they are aligned in a parallel to sub-parallel manner (Fig.4b).

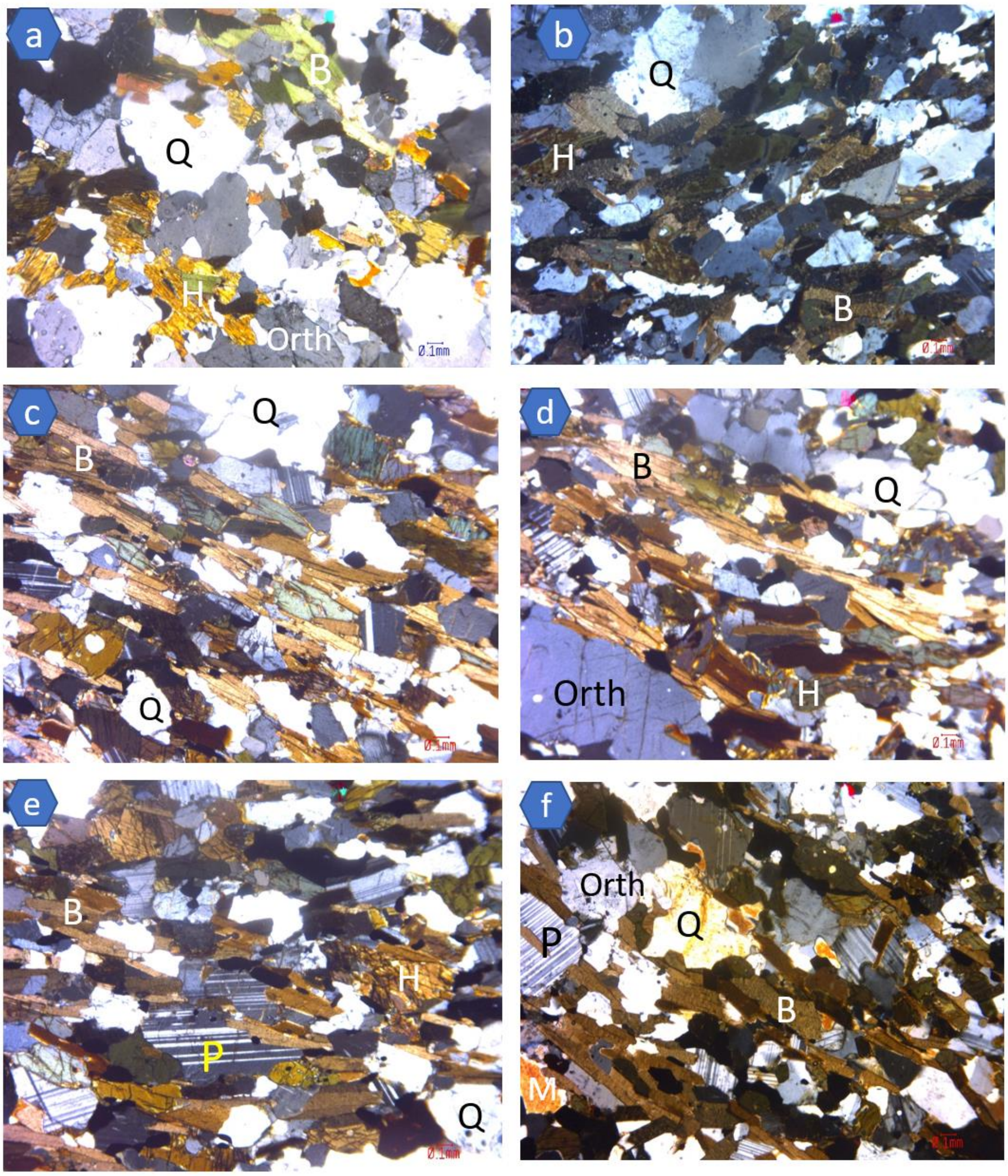

Fig. 4: Photomicrograph of medium-grained migmatite (a-b) from Idanre area in transmitted light (cpl) showing the constituent minerals; banded-gneiss of Ita-Ogbolu (c-d); and Ado-Ekiti granite-gneiss (e-f) showing quartz grains are isolated, feldspar shows faint twinning, biotite plates are aligned and stretched in diagonal direction while opaque occur in traces. Q (quartz), B (biotite), P (plagioclase), H (hornblende), M (muscovite), Orth (orthoclase).

Ita-Ogbolu Banded gneiss: This medium to coarse-grained, mesocratic to leucocratic rock is characterized by alternating layers of dark and light colours that define its banded structure. Microscopic investigation indicates that the rock is composed of quartz, orthoclase, muscovite, biotite, hornblende and opaque. Quartz content ranges from 43 to 45%, feldspar (21-25%), hornblende (9-12%), biotite (15-18%), muscovite (2-4%) and opaque (0-6%) of the modal composition. Porphyroblasts of quartz are scattered throughout the rock but few have their longer axis arranged parallel to the biotite. Some porphyroblasts of quartz measured up to 5 mm in length and 1.5 cm in width, while smaller grains measure between 2 mm long and 1 mm wide (Fig.4c). Clusters of quartz aggregates are arranged with stretched biotite plates to impact a seemingly gneissose foliation (Fig.4d). Biotite occurs as strongly pleochroic brown to greenish aggregates. Some blades have perfect bird view structure with jagged edges and moderate birefringence with reddish to yellowish brown maximum interference colours. It exhibits parallel to near-parallel extinction with maximum extinction angle of 30^o. Orthoclase crystals are large whitish-greyish in colour. Hornblende has low second order interference colour, it is pleochroic with straw green and dark-brown colour with some inclusions of quartz.

Ado-Ekiti Granite gneiss: This medium- grained rock generally has greyish outlook with little or no evidence of preferred orientation of the constituent minerals. Typical outcrops are intersected around Igirigiri area where the low-lying rock is extensive. The mineral constituents of the rock in hand specimen include quartz, orthoclase, biotite, hornblende, and muscovite. Petrographic examination revealed that the rock consists of quartz in the range of 39 to 43%, feldspar, (18-23%), hornblende, (2-5%), pyroxene approximately 6%, biotite, (12-13%), muscovite (7-10%) while opaque constitutes about 8%. Quartz occurs as angular to sub angular aggregates and they have clear crystals, biotite occurs as flaky masses and sometimes forming clusters that give the rock a characteristic granitic appearance. Though quartz and feldspar constitute about 65% of the rock mineralogic composition in hand specimen, optical examination presents about 36% mafic mineral contents. Feldspar occurs mainly as albite which are characteristically twinned (Fig.4e). Biotite occurs as bladed aggregate with profound lath-like habits and are well-arranged (Fig.4f). Muscovite shows whitish colour, bird view structure and platy habits. The plagioclase has bold albite twin laminae and maximum extinction angle of 24^o. Hornblende sometimes occurs in granular to columnar aggregates but with high relief. It has moderate to strong birefringence and the interference colours range from middle first order to upper second order and some even show up to third order brown colours.

RESULTS AND DISCUSION

The results of geochemical analysis of the migmatite and gneisses in the study area are presented in Tables 1-3. Mineralogical and modal composition (Table 1), Major elements compositions (Table 2) and Trace element composition (Table 3).

Table 1: Mineralogical and modal composition of the basement migmatite-gneiss rock units (in vol. fractions)

Sample no	1	2	Mean	3	4	Mean	5	6	Mean
Rock type	Idanre Migmatite			Ita-OgboluBandedgneiss			Ado-Ekiti Granite gneiss		
Minerals	Modal values								
Quartz	42	47	44.5	43	45	44	39	43	41
Feldspar	28	22	25	25	21	23	23	18	20.5
Hornblende	6	9	7.5	12	9	10.5	5	2	3.5
Pyroxene	-		-	-	-	-	6	6	6
Biotite	13	7	10	18	15	16.5	12	13	12.5
Muscovite	6	8	7	2	4	3	8	8	8
Opaque	5	7	6	-	6	3	8	8	8
Total	100	100	100	100	100	100	100	100	100

Feldspars are combinations of orthoclase and plagioclase.

Table 2: Major element composition (wt. %) of the migmatite-gneiss basement rocks

Rock	Idanre				Ita Ogbolu				Ado Ekiti			
Type	Migmatite				Banded Gneiss				Granite Gneiss			
Sample No	5 samples				5 samples				5 samples			
Oxides	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
SiO_2	64.18	65.47	65.00	1.03	60.85	63.60	62.53	1.21	59.91	61.83	61.01	1.08
Al_2O_3	14.18	16.04	15.17	1.09	14.76	18.71	15.93	1.06	13.47	15.95	14.96	1.13
Fe_2O_3	5.91	8.04	6.76	2.62	2.88	8.53	5.77	1.7	1.7	8.13	7.65	0.47
MgO	1.73	1.95	1.84	0.74	0.65	1.41	1.11	0.49	1.36	1.80	1.55	1.02
CaO	3.80	4.17	4.01	1.21	2.83	3.49	3.08	0.15	2.98	3.55	3.35	0.4
MnO	0.09	0.17	0.14	2.35	0.04	0.12	0.07	0.27	0.1	0.21	0.13	0.25
Na_2O	3.03	3.18	3.09	1.17	3.05	4.05	3.36	2.4	3.17	3.81	3.49	0.47
K_2O	2.94	3.92	3.40	1.68	5.25	6.51	5.87	1.45	4.62	5.64	5.03	1.2
TiO_2	0.60	1.62	0.89	2.2	0.2	1.8	1.09	0.33	0.95	1.49	1.31	0.21
P_2O_5	0.17	0.18	0.18	2.12	0.08	0.47	0.29	0.11	0.31	0.41	0.35	0.14
LOI	0.10	0.30	-	-	-	0.20	0.60	0.43	-	0.30	0.50	0.43

Table 3: Trace element composition (ppm) of the host migmatite-gneiss basement.

Sample	Idanre migmatite				Ita-Ogbolu banded gneiss				Ado-Ekiti granite gneiss			
Ppm	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
Ba	687	844	775.5	4.8	1567	2622	2085.3	4.3	1599	2201	1830.25	5.1
Be	3	4	3.75	1.6	2	4	3	1.8	4	6	4.75	1.6
Cs	0.5	0.6	0.54	1.0	0.3	0.3	0.3	1.1	0.1	0.3	0.18	1.1
Ga	16	16.2	15.9	1.2	16.4	20	18.65	1.3	20.8	27.6	24.05	2.4
Hf	5.2	5.7	5.63	2.3	4.2	14.7	11.6	1.8	23.5	42.4	30.39	2.5
Nb	14.5	21.8	17.13	2.1	8.8	48	35.7	2.3	30.7	83.5	58.63	1.8
Rb	138.3	151.8	144.3	3.5	163.4	203.5	188.68	4.3	134.8	218.6	175.33	3.2
Sr	313	352	339.13	2.9	280.2	366	317.85	5.1	582.7	921.4	757.5	4.7
Ta	0.8	1.0	0.9	1.0	0.5	2.8	2.1	1.0	1.18	3.34	2.35	1.4
Th	31.9	34.3	33.7	1.4	9.9	18.4	14.58	5.2	3.5	10.7	6.7	1.9
U	1.9	2.1	2.02	1.9	0.9	1.8	1.43	1.3	0.9	2.3	1.53	1.5
Zr	182.2	248.5	212.05	3.8	150.3	840	556.45	3.3	906	2025	1564.75	5.9
Y	33.4	36.1	34.05	1.2	21.1	49.5	35.65	2.4	25.8	50.3	39.1	3.8
Nb/Ta	16.1	18.2	17.05	2.6	16.8	17.6	17.13	1.6	24.6	26	25.13	2.3
Rb/Sr	0.39	0.46	0.43	1.0	0.55	0.61	0.6	1.0	0.21	0.25	0.23	1.0
Sr/Ba	0.41	0.5	0.44	1.1	0.12	0.21	0.16	1.1	0.26	0.57	0.41	1.6
La	57	63	59.48	2.5	62.7	142	98.68	2.5	103.4	137.4	125.88	2.5
Ce	107.3	124	112.7	4.3	111	282	187.8	4.1	187.9	285.9	239.9	1.7
Pr	11.38	12.8	11.95	1.2	12.6	29.9	21.12	2.1	27.4	33.99	28.73	2.6
Nd	38.4	43.1	41.33	3.7	43.6	106	74.43	3.9	89.2	131.2	109.35	4.4
Sm	6.94	7.53	7.22	1.6	7.37	16.72	12.65	1.7	18.6	27.7	22	3.2
Eu	1.29	1.45	1.38	1.1	2.34	2.74	2.62	1.7	3.31	4.86	4.12	1.5
Gd	6.22	6.81	6.52	1.4	5.38	12.5	9.9	2.4	10.03	16.37	13.77	3.4
Tb	0.88	1.01	0.94	1.0	0.78	1.81	1.43	1.2	0.86	2.07	1.55	1.4
Dy	5.35	6.01	5.81	1.8	4.31	9.75	7.68	1.6	7.92	11.25	9.68	2.5
Ho	1.09	1.51	1.33	1.3	0.72	1.92	1.29	1.3	1.23	1.92	1.59	2.4
Er	3.07	3.69	3.42	1.0	2.14	5.26	3.72	1.7	3.9	5.27	4.54	1.1
Tm	0.49	0.54	0.52	1.4	0.29	0.73	0.49	1.0	0.68	0.9	0.75	1.6
Tb	0.88	1.01	0.94	1.0	0.78	1.81	1.43	1.2	0.86	2.07	1.55	1.4
Yb	2.8	3.66	3.24	1.6	1.88	4.59	3.37	1.4	2.76	4.53	3.91	1.8
Dy	5.35	6.01	5.81	1.8	4.31	9.75	7.68	1.6	7.92	11.25	9.68	2.5
Lu	0.5	0.6	0.56	1.1	0.24	0.66	0.48	1.0	0.57	0.65	0.61	1.2

Geochemistry and major oxides diversities: The mineralogical and modal compositions of the migmatite and gneiss of the basement from Idanre (migmatite), Ita-Ogbolu (banded gneiss) and Ado – Ekiti are compared (table 1). Quartz compares well in the three localities as the mean shows that the Idanre has 44.5, Ita –Ogbolu 44 while Ado Ekiti has 41. Similarly, feldspar mineral takes a slight downward trend in occurrence with Idanre having 25, Ita –Ogbolu 23 and Ado Ekiti 20.5 in vol fraction respectively. However, in the case of biotite the vol. fraction of Ita –Ogbolu banded gneiss (16.5) is higher than that in Ado Ekiti granite gneiss (12.5) and lowest in Idanre migmatite (10).

Table 2 indicates that the migmatite and gneiss rocks in the study area are siliceous. Average SiO_2 decreases from Idanre migmatite (65%) to Ita-Ogbolu banded gneiss (62.53%) and Ado-Ekiti granite gneiss (61.01%). In re-appraising the percentage of average silica content of migmatite and gneissic rocks from different areas in Nigeria it is observed that the percentages of silica in migmatite and banded gneiss in the study area are lower than the porphyroblastic alkali gneiss (73.32%) and biotite gneiss (74.63%) from Iwaraja. The banded gneiss from Odo area (75.93%), and Iperindo gneiss (68.04%)

(Elueze, 1982) all from Ilesha area in South West Nigeria are higher than those from the study areas. Variations in geochemical features of rocks from different areas of the basement may be attributed to differences in lithologic associations. For instance, while gneisses in Ilesha area are associated with schistose rocks that of Idanre, Ita-Ogbolu and Ado-Ekiti gneisses are mainly associated with granites and charnockites. These variations might have equally resulted from remobilization during metamorphic recrystallization and orogenic episodes. However, the average silica content of Ado-Ekiti granite gneiss is comparable to garnet sillimanite gneiss from Obudu area in South Eastern (SE) Nigeria (Ekwueme and Kröner, 2006). Also, it is generally observed that siliceous rocks often have anomalously high alumina contents because Al_2O_3 is a common component of the alumina-silicate group of minerals which form substantial percentage of rock forming minerals. Al_2O_3 content of metamorphosed crystalline rocks in the study area (Idanre, 15.17%; Ita-Ogbolu, 15.93% and Ado-Ekiti, 14.96%) are higher than Jebba granite gneiss (11.84%). However, these values are lower than garnet sillimanite gneiss (18.87%) reported from SE Nigeria (Ekwueme and Kröner 2006). Alumina (Al_2O_3) contents with an average of 15.1% in Ado Ekiti migmatite (Talabi, 2013) is comparable with the Al_2O_3 in Idanre migmatite (15.17%). Alkali ($Na_2O + K_2O$) contents of the country rocks increases from 6.49% in Idanre migmatite, through 8.52% in Ado-Ekiti granite-gneiss to a maximum value of 9.23% in Ita-Ogbolu banded gneiss. Mean alkali content of Idanre migmatite (6.49%) is comparable to that in Obudu Garnet sillimanite gneiss (6.52%). Alkali content in Ilesha banded gneiss (7.55%) is slightly lower than that in the Jebba granite gneiss (7.96%). K_2O enrichment may largely reflect the presence of alkali feldspar or microcline in many Nigeria Precambrian rocks of granitic origin. Generally, the average K_2O values in the lithologic rock units under study are comparable to that in Jebba Granodioritic gneiss (Okonkwo and Ganev, 2012), Ibadan granitic gneiss (Grant, 1970), the Ile-Ife Grey gneiss (Rahaman, 1988) and the Igbeti Augen gneiss (Rahamann et al.,1983) all from Southwestern Nigeria. On average, three components (silica, alumina, and iron oxide) constitute 86.93%, 87.69% and 84.49% respectively of the bulk chemical composition of the Idanre migmatite, Ita-Ogbolu banded gneiss and Ado-Ekiti granite gneiss. The relatively high percentage concentration of these oxides (SiO_2, Al_2O_3, Fe_2O_3) is however expected and they are in consonance with similar rocks from the basement complex of Southwestern Nigeria. Figure 5 shows major element hacker diagrams which revealed that the various gneiss units exhibited negative correlation with increasing SiO_2 as all the major element compositions apparently decreased with increasing SiO_2 content. The overall decreasing trend is a resemblance of plots of a granitic rock that crystallized from a felsic magma whose original protolith may be a rock of granitic composition. However, alumina versus magnesia (Al_2O_3 versus MgO) plot (Marc, 1992) (Fig. 6) indicates that all the samples plotted within orthogneiss field.

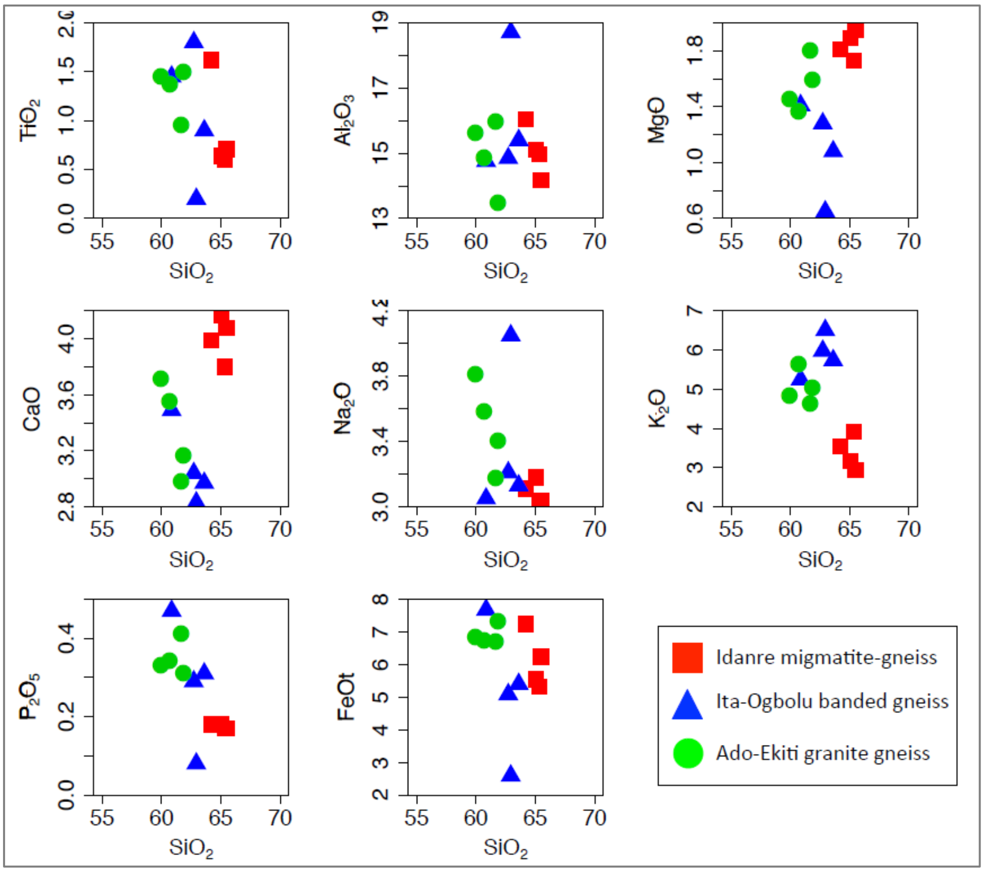

Fig. 5: Harker Variation diagrams of major elements for the rocks

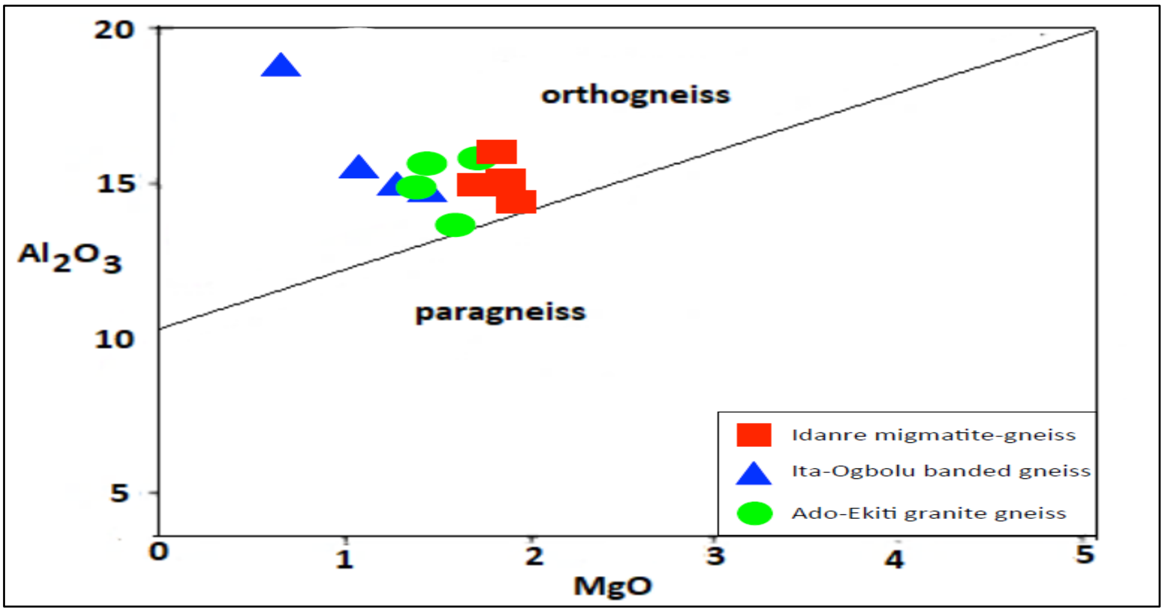

Fig. 6: Al_2O_3 versus MgO plot of the migmatite-gneiss rocks

Na_2O/Al_2O_3 versus K_2O/Al_2O_3 plot (Garrels and McKenzie, 1971) (Fig.7) indicated igneous origin for these basement gneisses.

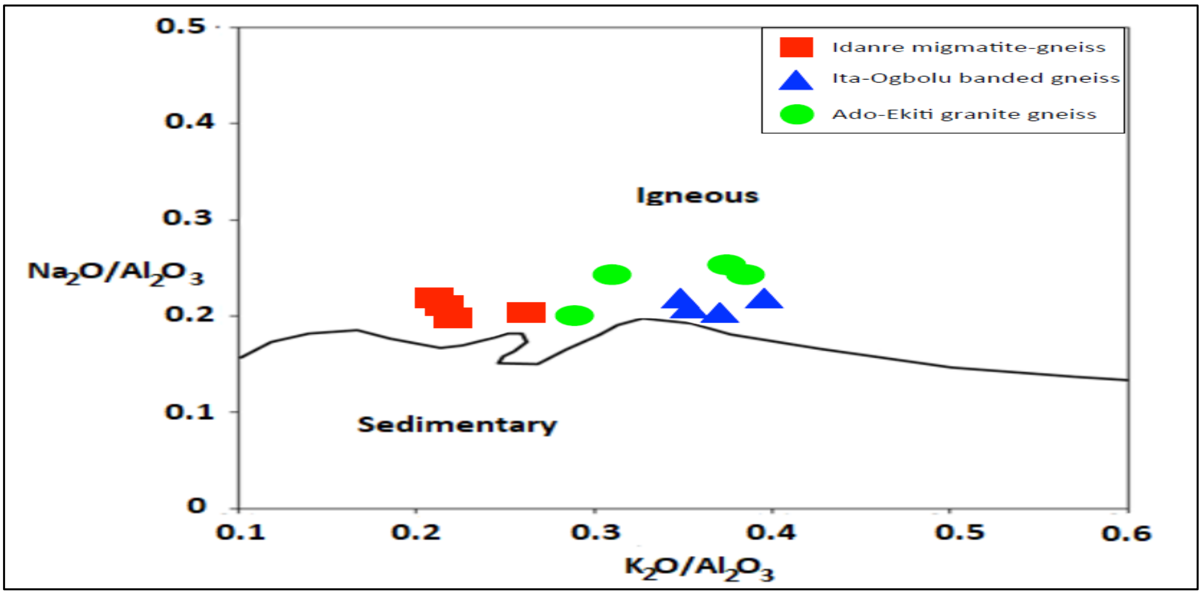

Fig. 7: Na_2O/Al_2O_3 versus K_2O/Al_2O_3 plot of the rocks (Garrels and McKenzie, 1971)

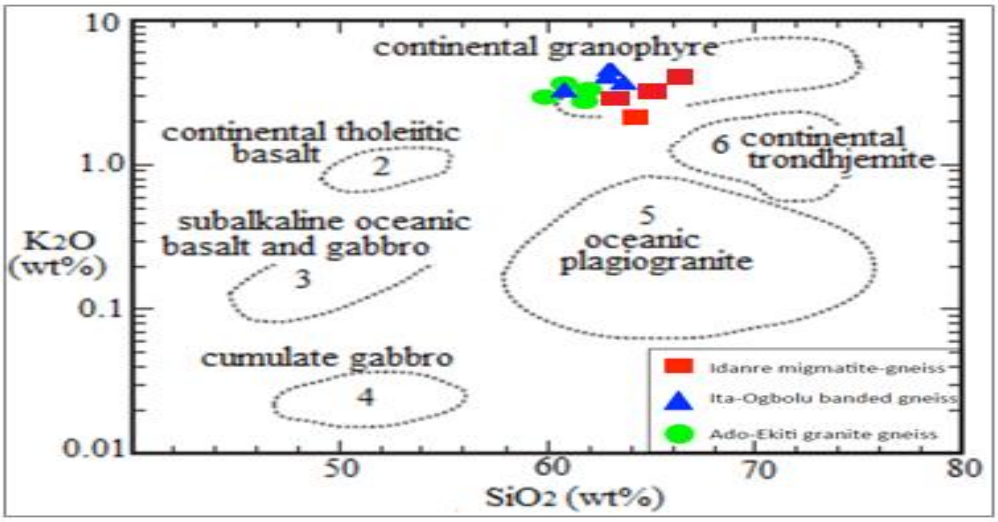

Fig. 8: K_2O versus SiO_2 diagram for the rocks

This is further supported by K_2O versus SiO_2 diagram (Fig. 8) where all the rock samples plotted within continental granophyre field. Generally, compositional features revealed a descending trend in the oxides of the basement rocks as shown; $SiO_2 > Al_2O_3 > Fe_2O_3 > K_2O > Na_2O > CaO > MgO > TiO_2 > MnO > P_2O_5$ (Fig. 9a). Precambrian terranes are affected by metamorphism globally. Best, (2003) suggested that geochemical patterns must be interpreted with caution because concentrations and ratios of many elements might have been perturbed.

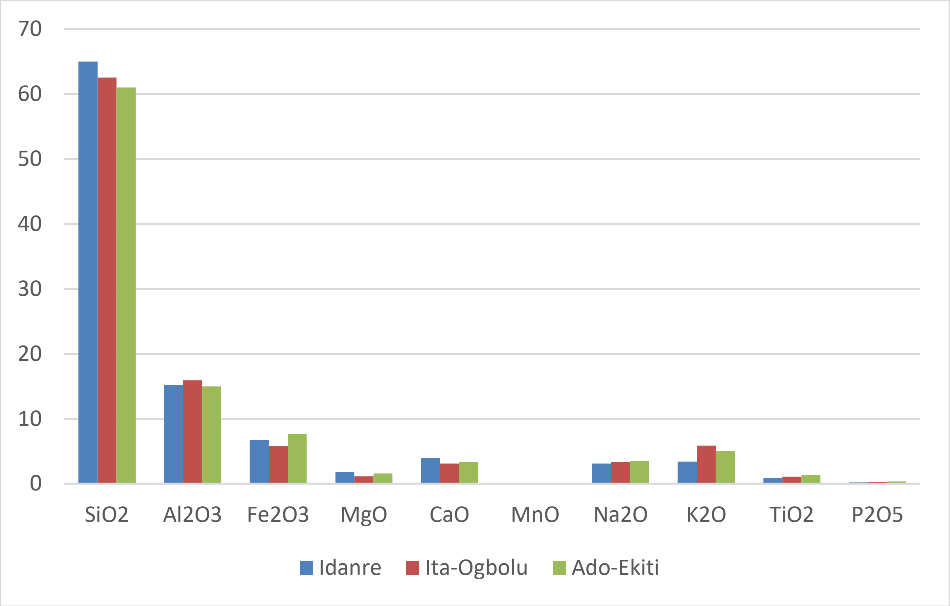

Fig. 9a: Major elements composition in the migmatite-gneiss units.

Best (2003) also believed that useful indication of pristine conditions includes constancy of element ratios, correspondence between chemical variations and those predicted by experimental data and petrographic observation, preserved textures, and lack of secondary minerals. He further stressed that less mobile elements, including HFSE (Ti, Zr, Ta, Nb, Th), REE (La, Ce, Nd, Sm, Eu, Gd, Dy, Er and Yb), Al, and Mg, are reliable petrogenetic indicators.

Table 3 shows the trace element composition in the basement rocks while Fig 9b indicated the enrichment of Ba, Sr, and Zr. This enrichment is expected for rocks of the continental crust as they form principal parts of lithophile group of elements which form the building blocks of most rock-forming minerals. Ba contents which range between 687 and 2431ppm compares well with similar rocks from the Ilesha schist belt area (Elueze, 1982). Rb/Sr ratios ranging from 0.24 to 0.58 ppm also compares well with the melanocratic biotite-hornblende rocks and microcline-plagioclase-biotite banded gneiss reported from southern parts of Ilesha and Iperindo (Elueze, 1982). The abundance of Zr and Hf characteristically incompatible in mafic magmas of these rocks points to their derivation from felsic magmatic source.

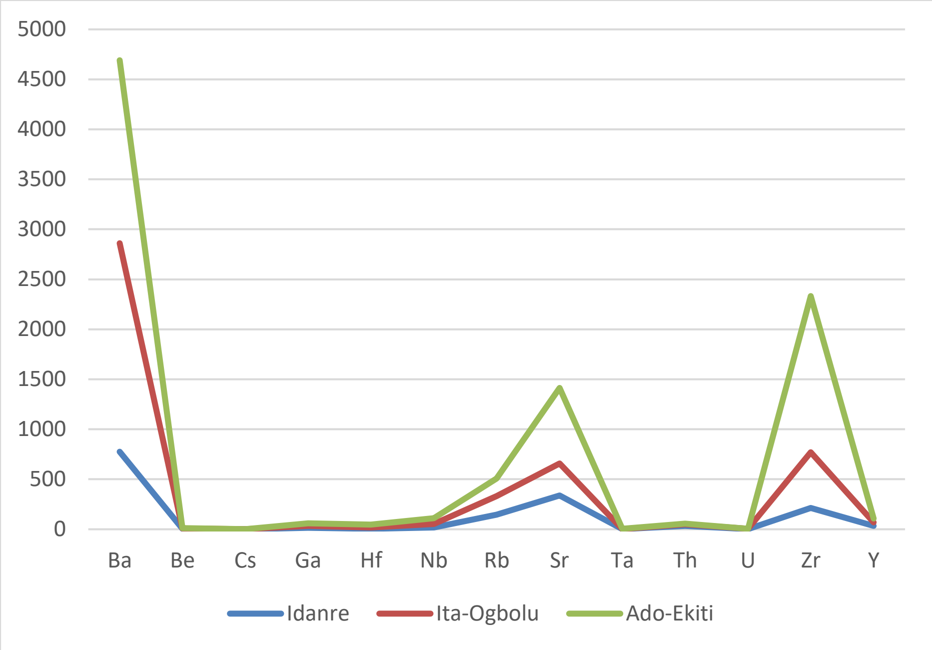

Fig. 9b: Trace element abundances in the migmatite-gneiss units (values in ppm).

The average Zr content from Idanre migmatite (212.05 ppm), enriched values of Ita-Ogbolu banded gneiss (556.45 ppm) and very high values of Ado-Ekiti granite-gneiss (1564.75 ppm) are all comparable to similar rocks from the basement complex of Nigeria and are within acceptable range for crustal rocks of granitic composition (Taylor, 1962). Rare earths elements (REE) show similar pattern and enhancement in Ce and Nd (Fig. 9c).

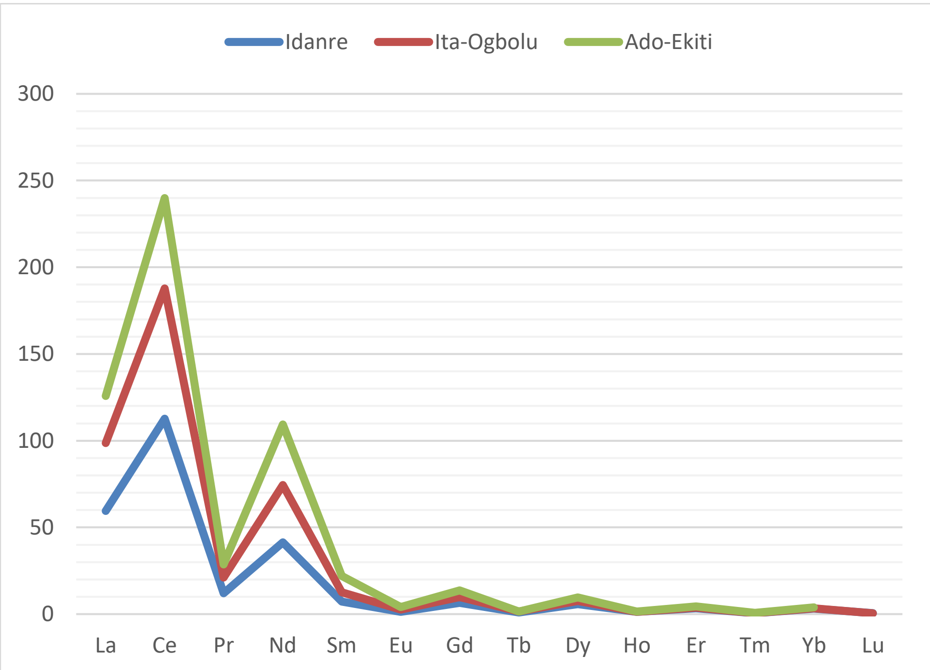

Fig. 9c: REE composition of the migmatite-gneiss rocks in the study area (values in ppm).

CONCLUSION

The study area forms part of extensive aggregated complex of migmatite-gneiss quartzite unit of Southwestern Nigeria. The migmatite-gneiss basement rocks vary significantly in their structural attributes but slightly differed in mineralogical features. The structurally heterogenous rocks are basal to other lithologic units across the entire basement. The units exhibit negative geochemical trends against SiO_2 for major oxide components and all the rocks show lithophile element enrichment. The migmatite-gneiss units have compositions comparable to continental granophyre and are products of different ancient materials subjected to multiple phases of orogeny and grades of metamorphism. The rocks are classified as orthogneisses and all have igneous parentage.

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