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GEOLOGICAL OBSERVATIONS OF BASEMENT ROCKS, AROUND GANAJA, KOGI STATE, NIGERIA

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ABSTRACT
A detailed geologic mapping coupled with petrographic mineral separation and geochemical studies were carried out on various rock types around Ganaja in Kogi state. The area is located between latitudes 7° 42/ and 7° 44/N and longitude 6° 42/ and 6° 45/ E and is about 29 square kilometre (29km^2). Mapping was done by transverse mapping method together with systematic sampling of the outcrops on a scale of 1:25,000. Field relations observed on the rock samples collected from this area coupled with available information and literature showed that the rocks belong to the migmatite gneiss complex of the south-western basement complex of Nigeria. The rock types within the area of study include migmatite, augen, gneiss (porphyroblastic granite gneiss) biotite gneiss and pegmatite. There were also minor occurrences of quartz and quartzo – feldspathic veins. Petrographic and chemical analysis of the rock samples from this area show the migmatites to generally consist of quartz, feldspar (plagioclase microcline and orthoclase) biotite and a few accessory minerals like epidote and zircon. The chemical analysis data and the petrographic studies of the migmatites mapped in the study area suggest its igneous parentage. However, with their uncomplicated mineralogical composition these migmatites differ from those of the north-eastern part of Lokoja which are of pelitic rocks parentage. It is being suggested that the deformational episode occurred along with the metamorphism of the various rocks of the mapped area and its environs causing varied metamorphic derivatives from the amphibolite facies to a higher metamorphic facies condition. These migmatites may have been formed from the metamorphism and metasomatism of fractionated igneous bodies during tectonism .The segregation and migration of the melting minerals such as quartz and feldspar in the rocks during regional metamorphism resulted in the banding of the leucosome (light) and melanosome (dark) minerals. The outcrops and their associated foliation generally trend in NNE-SSW and NNW-SSW directions.
KEYWORD: Ganaja migmatites, geochemical , metamorphism leucosome , melanosome.

INTRODUCTION
The area studied is situated at the extreme eastern part of the south-western Nigeria Basement complex. The area is made up of Basement complex rocks which include migmatite gneiss (augen gneiss or porphyroblastic granite and biotite gneiss) intruded by the NE-SW trending pegmatite dykes and covered by the Cretaceous – Recent coarse- medium grained sands to the East forming the coast of River Niger.

Covering an area of about twenty-nine square kilometres (29km^2) the location is bordered by latitude 7° 42/ and 7° 44/N and longitude 6° 42/ and 6° 45/ E (see figure1). Rocks in the area had regionally been described in the past by previous workers Hockey et al (1986), John and

Hockey (1964) Grant et al (1972) Odigi et al (1993), Pearce and Cann (1973), Pearce and Gale (1977). This study is presenting the result of a detailed geological field mapping, petrographic, geochemical and mineralogical studies principally to establish the petrogenesis of the migmatites and the associated rocks in Ganaja and environs in Kogi State Nigeria.

GEOLOGY OF THE NIGERIAN BASEMENT COMPLEX

The Nigeria basement complex forms a part of the north- south trending orogenic belt which Grant (1969), Ajibade and Wright (1989) had shown to extend westward into the Benin Republic, Togo, Ghana and eastward into Cameroun and northward into Niger Republic. The crystalline rocks which are exposed today rest on a pre-pan African old basement which is the sialic crust, Turner (1983).

The Nigerian basement complex consists of three broad lithological groups:

1. **Polymetamorphic Migmatite- Gneiss complex** which is composed largely of migmatite and gneisses of various composition and amphibolites, the relics of metasedimentary rocks represented by medium to high grade calcareous pelitic and quartzitic rocks occurring within the migmatites and gneisses and they have been described as "Ancient Metasediments" Oyawoye (1972). Isotopic ages varying from Liberian to Pan –African have been obtained from the rocks.

2. **Low grade sediment dominated schists** which form narrow belts in the eastern half of the country (figure 2) have been described as "newer metasediments" McCurry (1976) and unmigmatized to slightly migmatized shists ; Rahaman (1976) McCurry (1973) which was intruded by pan- African granitiods.

3. **Syntectonic to late tectonic granitic rocks** which cut both the migmatite gneiss complex and schist belts. The granitoids include rocks varying in composition from granite to tonalite and charnockite with smaller bodies of syenite and gabbro. Radiometric ages of the granitoids range from 750 -500 Ma which lie within the Pan-African age spectrum. These pan-African granitoids are called **older granites** in Nigeria to distinguish them from the Mesozoic tin bearing granite complexes of central Nigeria which are referred to as the **Younger granites** (figure 2). The regional rock in the mapped area is migmatite gneiss complex which comprises of relics of ancient metasedimentary sequences of Biotite and biotite- gneiss calc silicate rock, quartzite and quartz schist, all of which had been migmatised and strongly deformed. Migmatites in this area have also been described to vary in the degree of migmatization from one part of the migmatite gneiss complex to another, from outcrop to outcrop and even within a single outcrop.

Odigi (2002) has indicated that the migmatitic gneisses in the Okene- Lokoja area are meta igneous rocks which show mildly alkaline characteristics and are calc- alkaline in nature suggesting they were derived from an ensialic calc- alkaline magma.

FIELD OCCURRENCES

The major rock types that occur in this area are migmatites, augen gneiss and biotite gneiss while there are minor occurrences rock types like pegmatites, quartz and quartzo-feldspathic veins. Migmatites are the most wide spread rock type in the area and forms the country rock in which all other rocks occur. It is well exposed with mostly flat lying outcrop as well as seen in cutting across river and stream channels as highly weathered rocks. They are segregated into the levcosome and melanosome bands which generally trend in a N-S direction. The leucocratic band contains more than 70% of quartz giving it a light appearance and few amount of ferromagnesian minerals of mostly equigranular course- medium gained granitic texture. The ferromagnesian minerals usually biotite or hornblendes are common in the veins.

Migmatites cover about 50% to the east of the mapped area (figure1) and usually have sharp contacts with rafts of biotite and augen gneiss (plate 1). The trends of the fold axis are mostly east west with the plunging of the lineation usually to the north, reflecting the degree of deformation and plasticity.

The augen gneisses occur as isolated hills covering about 40% of the mapped area due to intense weathering activities they are wildly exposed and range from a height of about 200m at the western boundary to about 500m towards the south- eastern part of the mapped area. Texturally the augen is composed of quart zo-feldspathic coarse grained minerals within the ferromagnesian melanocratic matrix giving it a typical inequigrnular appearance. The mineral lineation usually strikes in a NE-SW direction while the augen gneisses have contact with migmatites and biotite gneisses in the area (plate 1) the augen gneisses usually form elongated S-N trending ridge at the western boundary and are widely scattered throughout the mapped area many of which occur as boulders.

The biotite gneisses from contacts with the augen gneiss bodies and migmatite usually at western part of the study area. There are occurrences of isolated conical mills around the augen gneiss bodies forming the remaining 10% of the rock types in the mapping area. The biotite gneisses are usually granitic in composition with biotite and hornblende forming the greater portion of the melanocratic component.

They have fairly regular banding resulting from mineral segregation in which predominantly dark bands vary in thickness from a few mm to several cm. local banding may be absent in which case the dark mineral tends to form streaky or lensoid aggregates aligned to form a rough foliation.

Pegmatite is one of the minor rock types which occur as dykes and veins cutting across the migmatite gneiss complex (plate1). They have an average strike of 45NW-SW and are exposed along stream channels and road cuts as well as areas of well exposed outcrops of migmatite bodies with an average width ranging from a few centimeters to a couple of meters. The pegmatites are coarse grained and are made up mainly of quartz (30%), feldspars (36&) and biotite (32%) hornblende and other minerals occur as accessory. Quartz and quartzo feldspathic veins are closely related to the pegmatite in space at some localities. They constitute the core of zoned pegmatite in migmatites. Thick concordant and usually closely joined veins are frequent. The mechanical weathering of quartz vein is common in the mapped area:

STRUCTURAL FEATURES AND TECTONISM

Field observations indicate that the basement rock have been subjected to many periods of deformation. The migmatite gneiss in the study area had undergone extensive migmatisation which may have nearly obscured and obliterated many of the earlier structures hence preventing comprehensive measurement and further interpretation of the structural evolution of the area.

However, the extent or degree of tectonism is expressed in the occurrence and the magnitude of metamorphism and metamorphic structures of the area such as foliation, minor faults, joints and fractures. There is the presence of deformed minerals and tectonic breciation of some of the crystals like tourmaline, feldspar, quartz in pegmatite which is a tectonic imprint in the area. There is also banding exhibited by the migmatite bodies (plate 1). The dominant structural trend of foliation,b dykes e.t.c. in the area is northwest as displayed by the strike of foliation banding and fault (figure 1). The same direction also controls the elongation of the pegmatite.

Foliation is a continuous or discontinuous layer structure in metamorphic rocks formed by the segregation of different minerals or by alternation of bands of different textures. In Nigeria most migmatites recognized so far appear to have formed through partial melting though metasomatic addition of Na^+, K^+ and B^{3+} appears to have also taken place particularly in the agmatite types, Ekwueme (1994). Injection of granitic magma driven along foliation planes, Olsen (1984) is thought to have triggered anatexis that formed migmatites of pan African age in NW and SE Nigeria (Ajibade 1988, Ekwueme 1991). In this area of study the structure has probably developed as a result of tectonic differentiation and metamorphic segregation. The preferred orientation of the foliation is dominantly in the NW-SE trend, which is indicative of the pan African orogeny.

Jointing in the area is generally a localized feature with multi- directional trends suggesting several phases of deformation. There were sets of cross cutting joints observed in the study area which is an indication of complex tectonism (plate 4). The joints trend mostly ENE-NNE, though some were open joints due to weathering. However, the joints are parallel to each other indicating their cogenetic relationship (common origin). Therefore, the forces or deformational episodes that led to their formation were the same.

MATERIAL AND METHODS

The field work started with a reconnaissance survey of the area, the access roads, drainage channels, types of settlements and also taking note of the minor and major outcrops. This was followed by the detailed geological mapping involving the transverse method of field mapping, collection of representative rock samples from outcrops, road cuts e.t.c. The geological hammer was used in collecting rock samples. Strikes and dips of outcrops, structures were taken with compass clinometers and their location recorded with the global positioning system (GPS). The rock samples collected were described megascopically (in hand specimen) in the field and then prepared for thin sections in the laboratory. Each rock sample that was studied under the microscope was first cut into a thin section with the rock cutting machine and mounted on glass slide with Canada balsam.

For the geochemical analysis, ten elements were determined using the Atomic Absorption spectrometer (AAS). The elements include Mg, Ca, K, Fe Mn, Na, Ni, Si, Al and Cu. While the model of AAS used is the Perkin Elmer analysis 200 spectrometer. Standard solutions were prepared accurately from the stock standard of 1000ppm by using the serial dilution formula $C_1V_1 = C_2 V_2$ from which the machine was calibrated to 2, 4 and 6ppm respectively.

RESULTS AND DISCUSSION

MICROSCOPE AND PETROGRAPHIC DESCRIPTION

Examination of the rock samples in thin section reveals that the major constituent minerals of the gneiss, pegmatites, migmatites and aplyte dyke are feldspar, biotitic, quartz and opaque minerals. These minerals were observed to be made up of different proportions in the rock samples as shown in table 1.

TABLE 1: MODAL COMPOSITION OF GANAJA ROCKS COMPARED WITH OTHER SIMILAR ROCK TYPES

MINERAL	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 6	SAMPLE 7	SAMPLE 8	SAMPLE 9
Quartz	20	40	30	20	35	10	30	39	30
plagiolase	20	40	40	20	26	16	35	12	12
Microcline	40	-	16	10	-	-	28	43	39
Orthoclase	15	5	5	20	8	-	-	-	-
Biotite	2	10	5	15	15	8	2	5	5
Moscovite	-	-	-	-	-	-	-	-	13
Epiodote	1	2	1	10	-	2	-	-	-
Zircon	-	-	1	-	3	3	-	-	-
Opaque	2	3	2	3	4	4	-	-	-
Hornblende	-	-	-	2	10	53	5	-	-
Actinolite	-	-	-	-	-	13	-	-	-
Sphene	-	-	-	-	3	-	-	-	-
Accessories	-	-	-	-	-	-	-	1	1

Sample 1-4: - Average modal composition for Gneisses from Ganaga Area (this Work)
Sample 5 - Average modal composition of mignatite Gneiss from Okene – Lokoja areas (Odigi 2002)
Sample 6 - Average modal composition of Amphibolite from Okene – Lokoja area (Odigi 2002)
Sample 7 - Average modal composition of Gneisses from North West Ekido, SE Lokoja (Imasuen et al 2009)
Sample 8 - Average modal composition of Augen Gneiss from Igbeti, SW Nigeria (Imeokparia and Emofurieta 1991
Sample 9 - Average modal composition of Banded Gneiss from Igbeti, SW Nigeria (Imeokparia and Emofurieta 1991) .

In table 1, the average modal compositions of Ganaja rocks are compared with the composition of similar rock types from other locations. The plagioclase feldspar in the rock samples from the area of study generally appears colourless under plane polarized light but it is pleochroic going from light to dark grey as the stage is rotated. It shows albite twinning with parallel extinction. The form varies from anhedral, subhedral to euhedral with a cleavage that ranges from perfect to imperfect. Some plagioclases have minor inclusions of quartz with subhedral form. Biotite mineral is brownish under plane polarized light with a slight pleochroism and a wavy extinction at a small angle of 2-3^0. Some of the biotite crystals range from euhedral to subhedral. There were inclusions of hornblende and euhedral opaque minerals.

The quartz mineral appeared colourless under plane polarized light with a low relief and vary from white to blue colour under crossed nicols. There was no visible twinning although the form is irregular from anhedral to subhedral. Opaques were observed as dark coloured minerals with parallel cleavage and high relief. There were no twinning but they have some quartz inclusions.

Epidote was observed as colourless to pale green under plane polarized light. It is slightly peochroic and exhibit prismatic elongate crystal with pseudo hexagonal cross section. The microcline is colourless in thin section but may appear cloudy due to alteration. The crystal forms are subhedral to anhedral and they have parallel cleavage. They also have extinction with angles ranging from 5^o to 15^o. They exhibit polysynthetic twinning corresponding to albite and pericline laws. Orthoclase appears colourless in thin section although turbid in some sections because of incipient alteration at boundaries with quartz. They display subhedral and anhedral crystals in phenocrysts with a perfect cleavage parallel to (0.01). The relief was low with extinction angles ranging from 5^o to 12^o. It shows Carlsbad twinning. Most of the thin sections generally show differentiation into leucosome and melanosome bands which is usually common in migmatites. The leucosome bands are made up of quartz, oligoclase, alkali feldspar and subordinate amount of hornblende in the augen gneisses. While the melanosome bands consist of plagioclase feldspar, biotite and green hornblende, the quartz which was in relatively high proportion (20-40%) occurs in two generations. The early quartz forms rounded inclusion in oligoclase crystals and tends to be interstitial in the quartz feldspar mosaic (otherwise called mymerrkitised quartz). A latter generation forms large compound crystals that appear to have been superimposed on the general fabric. Alteration of biotite is common as some rocks show biotite bounds with prophyroblastic quartz in a finer matrix. The green hornblende is associated with biotite in the melanocratic bands.

CHEMICAL ANALYTICAL RESULTS AND DISCUSSION

The result of the chemical analysis for the migmatite rock samples from Ganaja area compared with similar rock types from other localities are shown in Table 2.

TABLE 2: AVERAGE CHEMICAL COMPOSITIONS OF GANAJA ROCKS COMPARED WITH OTHER SIMILAR ROCK TYPES

oxides	Composition (wt %)						
	Sample I	Sample II	Sample III	Sample IV	Sample V	Sample VI	Sample VII
SiO_2	80.21	78.31	62.69	60.05	58.50	69.63	67.00
Al_2O_3	14.02	15.25	19.03	27.74	15.80	15.51	14.47
MgO	4.32	4.99	0.11	0.24	4.57	0.67	2.40
CaO	0.27	0.29	1.26	0.04	6.51	2.96	3.41
MnO	0.05	0.07	0.05	-	4.57	0.06	0.10
Na_2O	0.03	0.03	4.76	1.29	3.06	3.79	2.88
K_2O	0.01	0.01	2.69	1.52	2.22	2.23	4.29
Fe_2O_3	0.04	0.03	2.69	9.14	6.50	1.12	1.45
FeO	-	-	2.17	-	-	1.96	2.94
P_2O_5	-	-	0.18	-	0.25	0.3	0.10
CuO	-	0.01	-	-	-	-	-
NiO	-	0.01	-	-	-	-	-
LoI	0.30	0.10	-	-	-	-	0.80

Sample I = Average chemical composition of migmatite gneiss from Ganaja (this work)
Sample II = Average chemical composition of gneiss from Ganaja (this work)
Sample III = Average chemical composition of Hornblende biotite Gneiss from Agada, S, E Lokoja (Imasuen et al 2009)
Sample IV = Average chemical composition of Porphyroblastic Gneiss from N.W Ekido, S. E Lokoja (Imasuen et al 2009)
Sample V = Major Oxide composition of average crust (Fairbridge 1972)
Sample VI = Average chemical composition of Precambrian Gneiss Igbeti Area S.W Nigeria (Imeokparia and Emofureta 1991)
Sample VII = Average chemical composition of Iseyin banded Gneiss (Rahaman 1973)

The average of SiO_2 for the migmatite rock is between 60 and 80% while Al_2O_3 varies from 14 to 16%. The analytical values for the Ganaja rock samples compare favourably with those of similar rock types from other areas. CaO values are generally low, about 0.30% while MgO values vary between 4.32 and 5.00%.

However, the presence of plagioclase feldspar in the migmatite explains the significant content of Al_2O_3 and CaO in the samples. The Mac- Donald and Katsura (1954) diagrams of Na_2O+K_2O(wt%) versus $Si0_2$(Wt%) is used to discrimmate rocks of high alumina, alkaline and tholeeitic composition. Values on the plot for samples from Ganaja area show that the migmatites are mildly alkaline with high content of $Si0_2$ (figurer3). Using the Na_20/Al_20_3 versus K_20/Al_2O_3 diagram developed by Garrels and Mackenzie (1971) the values for the Ganaja migmatite rocks plot in the igneous field (figure4) indicating that they are probably of igneous origin.

The migmatites represent metamorphosed products of fractionated igneous bodies as suggested by Odigi (2002). The relatively high Mg0 values and the Ni content in the rock samples from the area of study (table 2) probable indicate the presence of olivine in the primitive magma. The low K_20 contents of the analyzed samples are unlikely to reflect original igneous chemistry and possibly suggest evidence for metasomatism. These migmatitic rocks could approximate to low temperature melting compositions at high PH_20 in 0-ab-or-H_20 and hence may be products of hydrous igneous fractionation process at high pressures, Turner (1983).

CONCLUSION

The major rock types within the mapped area are migmatite, augen gneiss, biotite gneiss, minor pegmatite and aplyte dykes. The gneisses (augen, porphyroblastic granite, biotite gneiss) are the oldest rock in the area and are probably products of an early orogenic event. While the pegmatites represent the youngest rock in the area occupying the fractures and available openings in the country rock.

The area is suggested to be part of a metamorphic terrain of the south western basement complex of Nigeria. Formation of the different rock types in the area is most probably connected to the past tectonic events that affected the area and has greatly influenced the structural and textural features of the rock.

Based on previous work and as indicative in this work the area has undergone at least two tectonic processes since the rocks are shown to have been variably metamorphosed. Structures in the area have dominant NW-SE trend directions which correspond to the predominant stress direction that represent the imprint of the pan-African orogeny. The mineralogical and geochemical analytical data from this area of study compare favourably with similar rock types from other areas; however, they suggest the migmatitic rock to be of igneous origin. They are characterized by the cal-alkaline composition from the Fe_2O_3 and Mgo content which were formed from the partial melting of the igneous rock parentage. Pressures resulting in textural modification predicted metamorphic conditions and Mn, Na, Ca, K, Fe, Mg, Al, and Si pseudo sections are compatible with partial melting and local segregation of melt into quartz – plagioclase to orthoclase at a low angle to schistocity. The most important melt compositional variation in prediction are tied to the modeled water content because water acts as flux for quartz- plagioclase melting which produces a rapid increase in silica (S_iO_2) in the melt. In this investigation only slight discrepancies between melt compositional prediction and observed leucosome compositions are noticed for S_iO_2, Al_2O_3 and Na_2O. However, significant discrepancies which are evident for K_2O, CaO may be products of leucosome modification process such as fractional crystallization with melt escape and/or back reactions between melt and country rock.

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REFERENCES

Ajibade, A.C and Wright J. B (1989) the Togo- Benin , Nigeria shield- evidence of crustal aggregation in pan African belt. Tectonophysics, 155 p125-129.

Ajibade A.C (1988) Structural and tectonic evolution of the Nigeria basement with special reference to NW Nigeria. International Conference proterozoic Geology and tectonics of high- grade terrain, Ife, Nigeria.

Ekwueme, B. N (1991) The geology of the area around Obudu cattle Ranch, south eastern Nigeria. J .Min Geol 27 p 129-134.

Ekwueme B. N (1994) Structural features of Obudu Plateau, Bamenda Massif Eastern, Preliminary Interpretation J. Min Geol 30(1) p 45 -59.

Garrels, R.M and Mackenzie. F (1971) Evolution of sedimentary Rock, Norton and Co: New York 394pp

Grant , N.K (1969) The late Precambrian to early Palaeozoic pan African Orogeny in Ghana , Togo Dahomey and Nigeria Geol Soc Ame. Bull.80 p45-56

Grant , N.K. Rex, D and Freeth , S J (1972) Potassium Argon Ages and Strontium Isotope ratio measurement from volcanic Rocks, North-eastern Nigeria: Contri. Mineral Petrol 35 p 277-292

Jones, H.A and Hockey R.D (1964) The Geology of part of south western Nigeria. Geol Survey Bull No 31 p 2

MacDonald G.A and Katsura T (1954) Chemical Composition of Hawaiian lavas J, Petrol 5 p 82-133

McCurry, P (1976) The geology of the Precambrian to lower Paleozoic Rocks of Northern Nigeria , Elizabethan pub co, Lagos p 155.

McCurry, P (1973) Geology of Degree Sheet 21, Zaria Nigeria Overseas Geol Mineral Resource London 45p.

Odigi, M. I (2000) Geochemistry and Geotectonic setting of Migmatitic Gneiss and Amphibolites in the Okene- Lokoja area south western Nigeria Journ Min Geol vol. 38 p 81-89

Odigi, M.I Ozepue, M.C and Onyeagocha,A.C (1993) Geochemical evolution of pan African Magmatic rocks of the Basement complex S.W Nigeria . J . African Earth. Sci. vol. 17 p 541-552.

Oyawoye, M. O (1972) The basement complex of Nigeria in African Geology edited by T. F. J Dessau Vagie and Whiteman, A. J, University of Ibadan p 66- 102

Pearce J. A and Gale G. N (1977) Identification of ore Deposition Environment from Trace Elements in Volcanic Processes in ore Genesis Inst. Min and Metal and Geol Soc. London.

Rahaman. M. A (1976) Review of the basement geology of south western Nigeria in Geology of Nigeria edited by C. A Kogbe. Elizabethan pub. co, Lagos p 41-58.

Russ W.(1957) The Geology of parts of Niger, Zaria and Sokoto Province. Geol Survey. Nigeria Bull 27 p 42.

Turner D.C.(1983) Upper Proterozoic Schist Belts in the Nigeria Province of West Africa, Precambrian Res. 21 p 55-59.

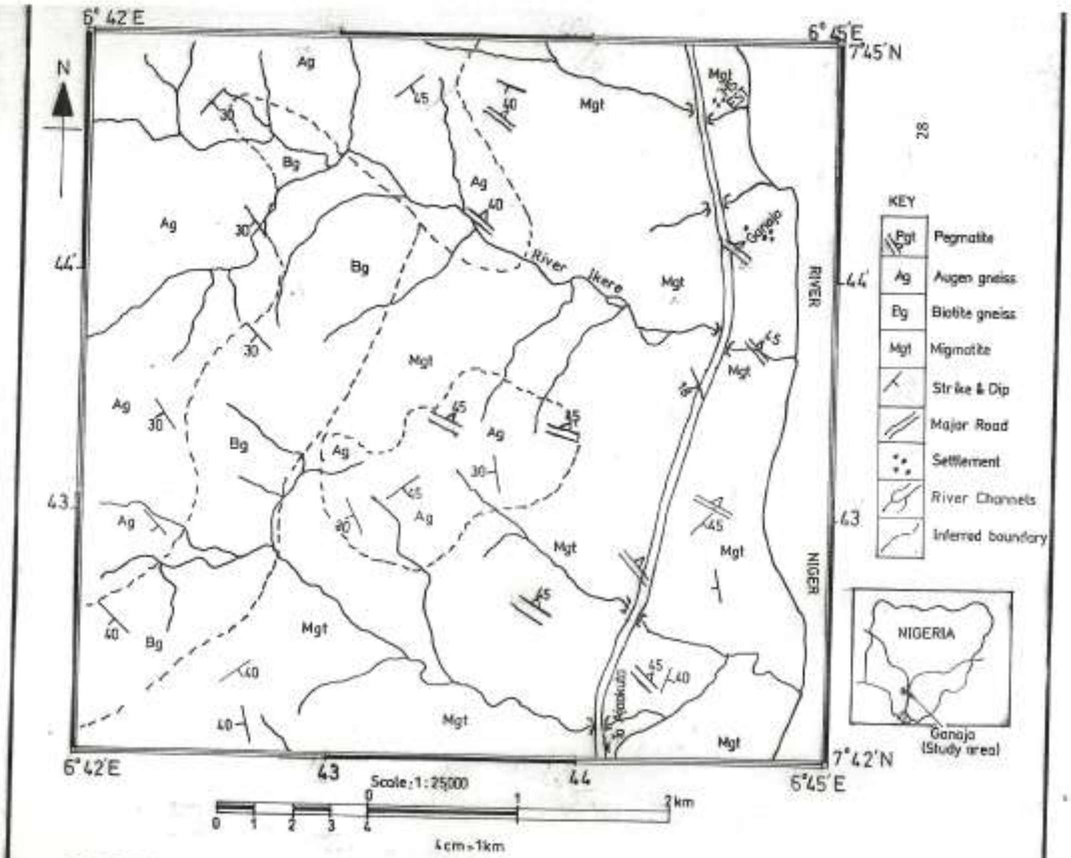

Fig.1. Geological map of the area around Ganaja near Lokoja, Kogi State, Nigeria. (sheet no. 247 S.W)

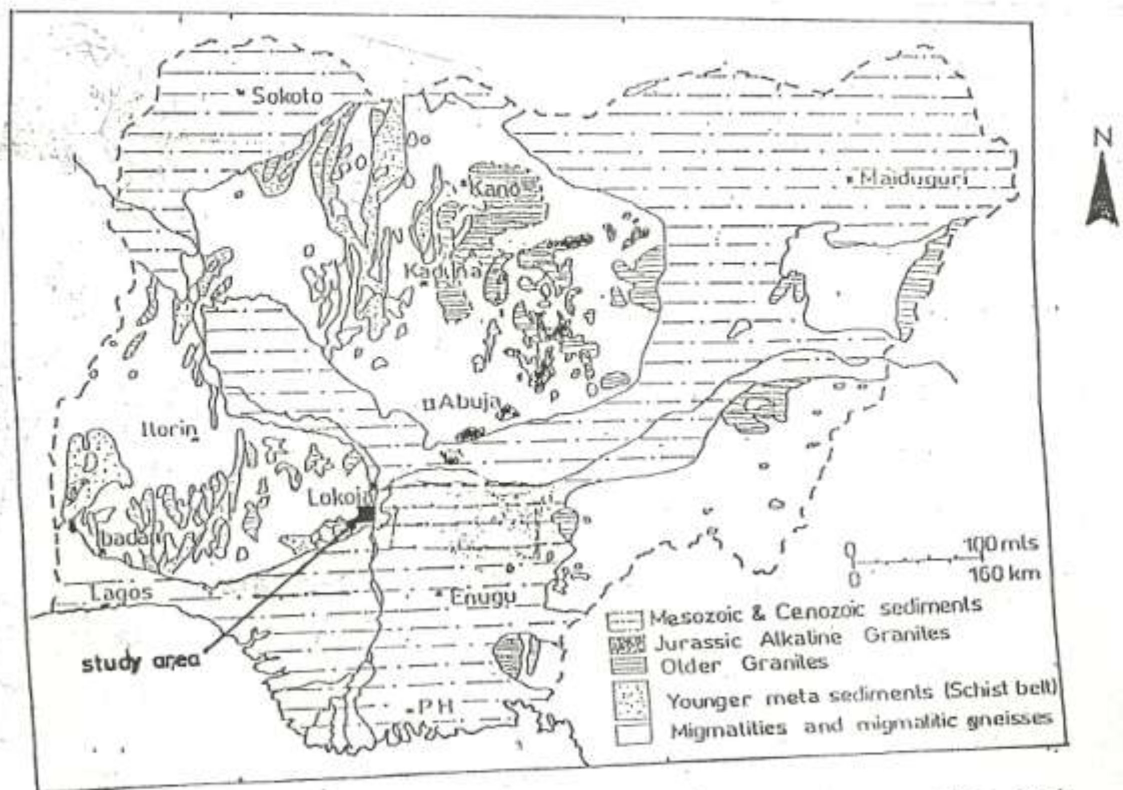

Fig. 2. Geological map of Nigeria showing the three major rock units in the Basement Complex, as well as the Jurassic granites which intruded the Basement (modified after Oyawoye, 1972)

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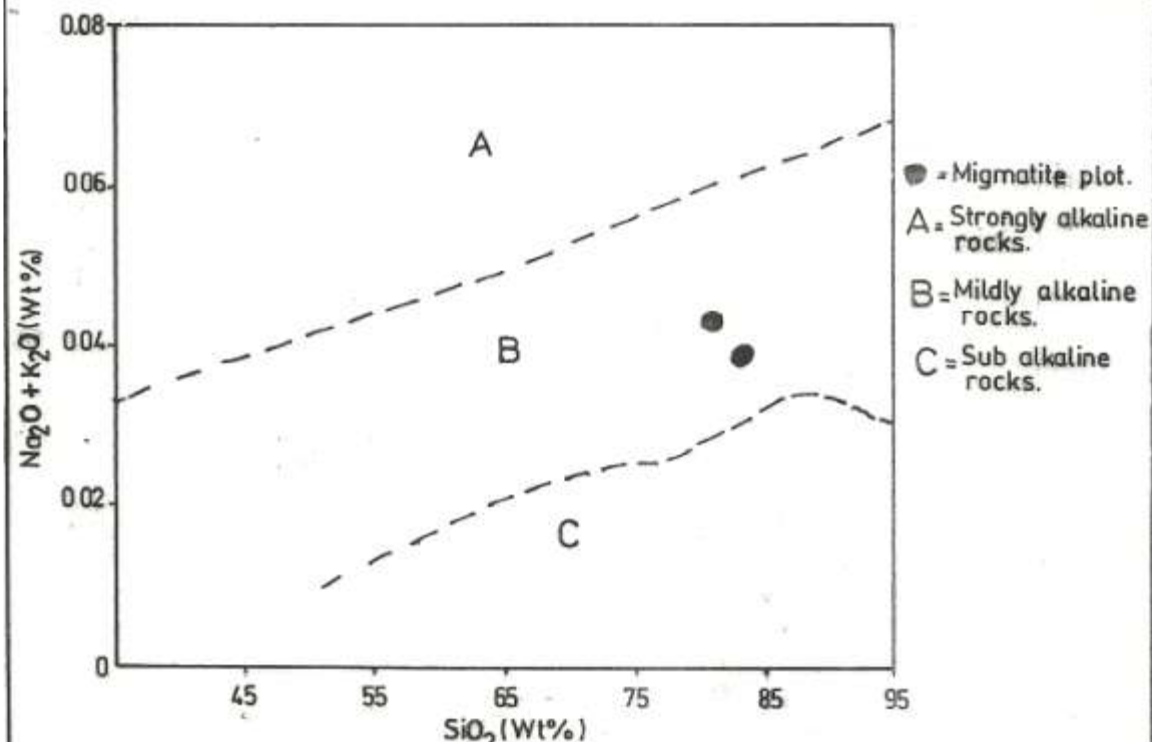

Fig.3. Plot of $Na_2O + K_2O$ versus SiO_2 of Migmatitic rocks from Ganaja area.
(Modified after MacDonald and Katsura 1954).

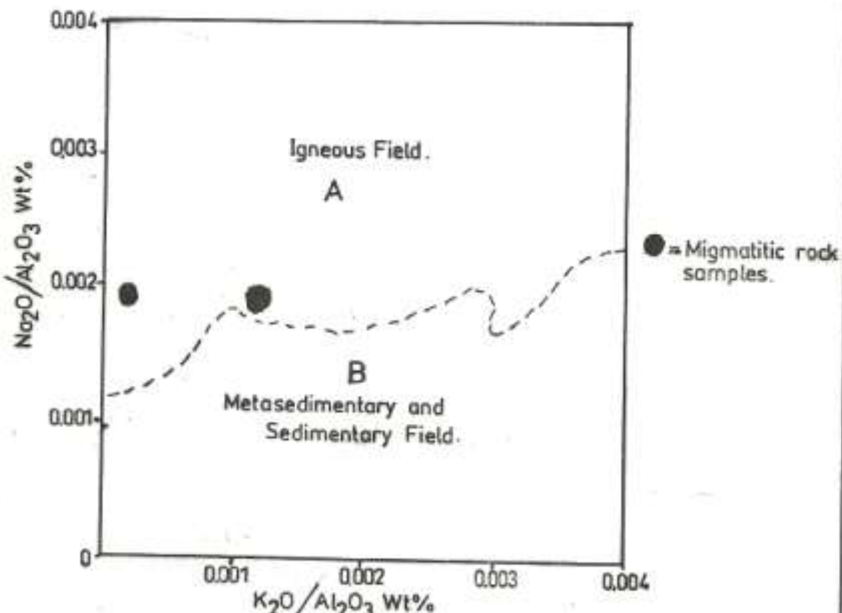

Fig.4. Plot of Na_2O/Al_2O_3 versus K_2O/Al_2O_3 of Migmatitic rocks in Ganaja area.
(Modified after Garrels and MacKenzie 1971).

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Plate 1:

Polymytic migmatitic body with an augen shape body of plastically deformed gnesiss.

Plate 2:

A sharp contact between augen body (RS) and biotite gneiss body (LS)

Plate 3
A pegmatite dyke crossing across a massive augen gneiss body geological hammer lies on the pegmatite dyke.

Plate 4:
Highly jointed augen body.