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Lithology and Field Relationships of the Granitoids of Bauchi District, Northeastern Nigeria

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Abstract

Bauchi district is part of a large basement complex in northeastern Nigeria characterised by extensive exposures of granitoids. Field mapping of the area at a scale of 1:50,000 shows that the area is underlain by three broad lithologic units viz: migmatite/gneiess, bauchite and granites of various textures. These rocks are largely composed of hornblende, pyroxene, plagioclase, biotite, microcline, quartz with accessory apatite, zircon, sphene and magnetite in various proportions. The rocks host enclaves of various shapes and sizes and are separated from one another by predominantly gradational contacts. The distribution of enclaves throughout the granitic unit, their sub-rounded shape and transitional contacts with the host rock are consistent with their igneous texture that the enclaves are syngenetic probably representing remnants of pre-existing rocks from which the granitoids were sourced. Interpretation of both the mafic enclaves and gradational contact relationships has led to a provisional conclusion that the granitoids are probably I-type genetically related to a common source by fractional crystallisation of hornblende, plagioclase, biotite, microcline and accessory apatite, zircon and sphene. Petrochemical study is needed in order to assess more accurately the genetic relationships of the various rock units as the present study can only give an insight into this aspect.

Keywords: Nigeria, Bauchi, Lithology, Granitoids, Bauchites.

Introduction

Bauchi district, the study area is situated at the eastern margin of the Northern Nigerian Basement Complex and lies between longitudes 9°45’ and 9°59’ East and latitudes 10°08’ and 10°23’ North. The country is more or less of flat plain punctuated by geological features which in most places demarcate their topographic forms. The various rock units form prominent rocky hills. For instance, clusters of hills comprising Inkil, Guni and Wurinji hills in the east central part of Bauchi town are composed of bauchite. In the southern part, chains of hills that tend to be elongated in a north-east south-west direction, parallel to the general strike of the foliation in the rocks are common. Prominent among them is the Buli hills which is composed of bauchite. Similar but low-lying hill country underlain by different rock units is developed in the northern and far eastern parts of the district. In these places, elongate and sub-circular isolated hills of granites, migmatites and gneisses are found and extend beyond the study area to neighbouring districts.

Most of the earlier works on the granitoids of northeastern Nigeria were conducted in the first half of the 20th century. Reconnaissance survey of the area was first made during the mineral survey of northern Nigeria in the first decade of the century[1]. The result of the survey was greatly improved upon by subsequent geological mapping of the region on a scale of 1:100,000. This systematic mapping started with the work of Bain,[2] who described the granitoids of Bauchi in some details. This systematic mapping continued till the early part of the sixth decade during which portions of survey sheets nos. 86, 87, 109, 194 and 195 were mapped and the basement rocks of the region, including Bauchi area, investigated[3]. Since then, the granitoids of Bauchi has received less attention from workers on the Nigerian Pan African terrain. Consequently, there is paucity of recent geological information on the granitoids. This work is part of an on-going effort aimed at enlarging existing information on the granitoids.

Regional Geological Setting

The oldest sedimentary rock of any country is normally underlain by rocks that have been extensively altered by heat and pressure. In Nigeria such rocks are called the basement complex and consist of the following groups: i. Migmatites, gneisses and quartzites, ii. Metasediments and metaigneous rocks, iii. Granites and granite gneisses, iv. Charnockites, diorites and gabbros, v. Volcanics and hyperbyssals.

Although Ajibade, et al.[4] geologically divided the Nigerian Basement Complex into the Western and Eastern Provinces, they can be geographically divided into three viz: the Western Nigerian Basement Complex, the Eastern Nigerian Basement Complex and the Northern Nigerian Basement Complex (Figure-1). These Basement Complexes occupy three geographical regions in the country. The Western Nigerian Basement Complex constitutes the southwestern part of the country and extends into the Republic of Benin. The Eastern Nigerian Basement Complex, believed to be a westward extension of the Cameroon basement complex into Nigeria, occupies three regions (Hawal Massif, Adamawa Massif and the Oban Massif.) along the country's eastern border with Republic of Cameroon. The Northern Nigerian Basement Complex covers an extensive area north of rivers Niger and Benue and is composed of schist belts in the western part (around Kaduna) and large masses of granitoids in the central and eastern parts intruded by the Younger Granites around Jos. The three basement regions are separated from one another by Cretaceous to Recent sedimentary basins. The granitoids of Bauchi are part of a large volume of crystalline rocks in the eastern margin of the Northern Nigerian Basement Complex.

In the Bauchi district, one most distinctive and highly unusual member, (a dark-green, porphyritic rock), of the basement complex had attracted the attention of some workers including Falconer[5], Bain[2] and Oyawoye[6]. The nomenclature of the rock had continued to change. Falconer had described the rock as coarse-grained 'augen granite'. Bain called it porphyritic Older Granite 'syenitic type' while Oyawoye described it as fayalite-quartz-monzonite and using the name of the type locality, Bauchi, he named it 'Bauchite'. Oyawoye[7] and Oyawoye[8] believed that Bain[2] who earlier named it pyroxene syenite, had mistaken fayalite for enstatite and ferrohedenbergite for magnesium diopside. In this work, the name Bauchite will be retained throughout. Similarly, the granitoids with prominent microcline porphyroblasts which have been variously described as hard gneisses[8], feldsparthic granites[2] and biotite granite[7] will be grouped together with other granites (e.g. hornblende biotite granite) and simply called granites. All gneisses (e.g. biotite gneiss, agmatitic gneiss and lit-per-lit gneiss) will be called gneiss and only differentiated where evidence are very clear in the field.

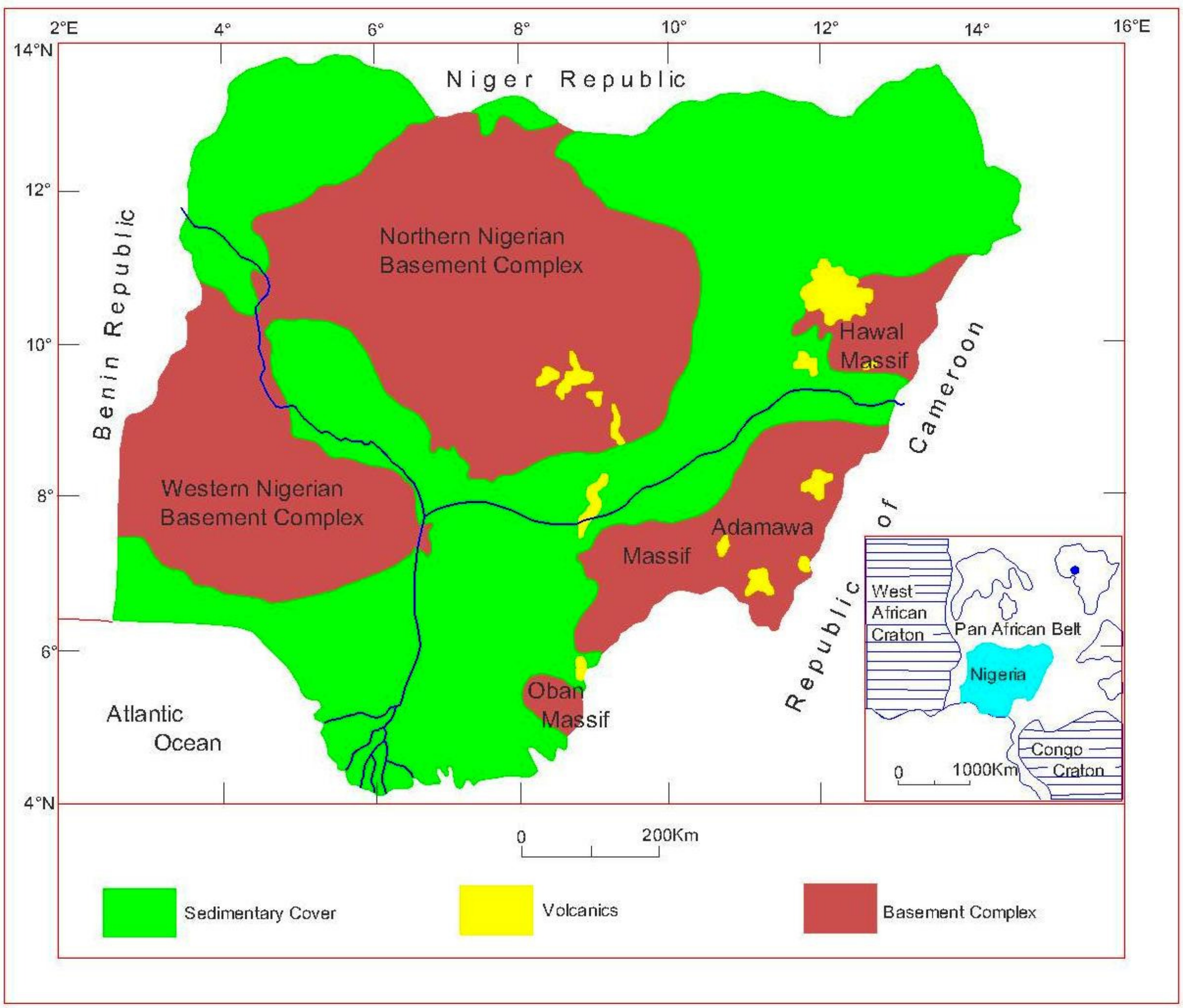

Figure-1
Generalised Geological Map of Nigeria[9]

Field Procedure: Bauchi town has many federal highways that radiate from its centre. These highways include the Kano road, Maiduguri road, Jos road, Gombe road and Dass road. Each of these highways has several feeder roads which are in turn linked to many footpaths that connect the villages. These networks of roads and footpaths make the various outcrops and exposures within the district easily accessible. The field mapping exercise was conducted along traverses planned to run across the rocks outcrops. The sampling exercise was guided by changes in texture, colour and macro-scale mineralogy of the rocks. Samples representing a wide spectrum of rocks were carefully collected. Great care was taken to ensure that weathered samples were not collected. So, the collected fresh samples were properly labeled and transported to the petrology laboratory of Applied Geology Department, Abubakar Tafawa Balewa University Bauchi where thin sections were prepared and petrographically studied using a high magnification polarising microscope. Canada balsam was used as the mounting medium.

Results and Discussion

Lithology and Field Relationships: Migmatite and gneiss: Migmatites and gneisses have complex relationship and structures in the field which could not allow for separate mapping of the two rock units. They were therefore presented simply as migmatite gneiss on the field map but described separately here in the text. Migmatites are abundant and widespread in the northern part of Bauchi occupying areas around Kano road from Nigerian Army Armoured Corps and extending beyond the study area where they give way to gneisses at Gubi Campus (Figure-2). Migmatites (Figure-3a) also extend eastward to the northern part of Yuli village along Maiduguri road forming an extensive transition zone between the medium-grained granites and the gneisses. In the eastern part of Bauchi town, migmatites occur outside the study area and shortly before and beyond Kangere village along Gombe road. The migmatites are practically absent in the southern part of Bauchi and do not appear to have any contact with the bauchites.

Gneisses are highly variable but two varieties are important – the variety with fairly regular structure and that with irregular structure. The variety with regular structure has discontinuous foliation and consists of almost parallel bands of gneissic and granitic rocks (Figure-3b). Generally, the bands are consistent in strike direction and concordant with the foliations. They are mostly narrow and may vary in width from about a centimeter to several meters in length. While the gneissic bands are darker and consist of thin parallel strings of biotite and quartz aggregates, the granitic bands are light coloured and composed dominantly of quartz and feldspar. This variety is of restricted occurrence occurring in a locality some few kilometers before Gubi Campus.

In some localities along Maiduguri road, the granitic bands are replaced by larger pegmatite dykes that are generally concordant with the foliation of the gneisses and have consistent strike direction. The pegmatites commonly show zonal distribution of its minerals with quartz frequently occurring along a central line surrounded outward by large microcline crystals. Towards the migmatites – gneiss contact at a quarry along Maiduguri road, aplitic dykes, aplitic and pegmatitic segregations crisis cross the country rock forming almost half the volume of the rock (Figure-3c).

Another variety has irregular blocks of gneisses highly dissected discordantly by granitic dykes. Like the gneissic bands of the gneisses with regular structures, the gneissic blocks of this variety are generally dark to grey in colour. They however show foliations which are more discontinuous and the banding frequently disrupted than the first variety. The disrupted bands form short discontinuous lenses (Figure-3d). In spite of the structural differences, the two varieties of the gneisses are texturally similar.

In general gneisses of the study area are characterized by discontinuous foliation, disrupted alternate light and dark coloured bands of fine- to coarse-grained texture with both discordant and concordant structures. Collectively these features support formation of the gneisses by penetration of the country rocks by granitic materials. The absence of even-textured granitic rocks and feldspar augen argues against formation of the gneisses by permeation of the country rocks by granitic materials that would produce an even-textured granitic rock with vague banding or give rise to the growth of feldspar augens.

The transition from gneissic terrain to granitic terrain is marked by a gradual reduction in gneissic textures/structures and increase in granitic texture. Thus, the density of the bands of gneisses alternating with the granitic material gradually reduce as one moves away from gneiss areas to granite areas where such structures are completely absent.

The Granites: Two varieties of granites were also observed – the biotite hornblende granite (which is generally porphyritic in texture) and the biotite granite (which appear equigranular with some stretched mineral grains). The biotite hornblende granites are the most-wide spread of all the rocks in Bauchi area. They are so wide spread that they appear indistinguishable in most geological literature of the area. They generally occur as large intrusive masses occupying areas of several tens of square kilometers such as found around Mangas in the southern part of Bauchi area. These rocks are believed to be products of extensive partial melting and granitisation connected to the Pan African orogeny. Eastward beyong the study area, the biotite hornblende granite weather to give rise to kaolinite around Alkaleri.

The granites unlike the migmatites and gneisses are variable in texture, colour and mineralogy. In texture they vary from equigranular (consisting of grain sizes ranging from 0.1cm – 0.2cm) to porphyritic with feldspar phenocrysts measuring 2cm x 3cm to 4cm x 5cm. In colour they vary from pink to grey reflecting a change in composition from acid to basic. Cross-cutting relationship has help to establish that the acidic types are latter to the intermediate and basic variety. The biotite granites occur in the eastern part of Bauchi town where they form a transitional zone between the bauchites at Inkill and the migmatites after Kangere village. This transition is associated with colour change from pink to grey as one move towards Kangere. Here, the equigranular granites contain xenoliths of older gneissic materials. At Inkill towards the contact zone, mafic enclaves (Figure-3e) and dykes (Figure-3f) of granitic materials measuring about 3 meters in width are found within the bauchites. In the northern part, the biotite granites fades into the migmatites which imparts lineation on the granites at the boundary zone between the two rocks. The biotite hornblende granites cover almost the whole of the far southern part of Bauchi town around Mangas and extend northwards, progressively decreasing in grain size and changing in colour from different shades of grey to pink until the base of Buli Hills where it makes a gradational contact with bauchite (Figure-2). Another exposure covering areas north and south of Abubakar Tatari Ali Polytechnic extends eastwards for about 5 kilometers along Jos road where it is being exploited for dimension stones by Julius Berger Construction Company. Within the granite, subordinate diorite occurrence is found between the Buli Hills and Lushi in the southwestern part of Bauchi town.

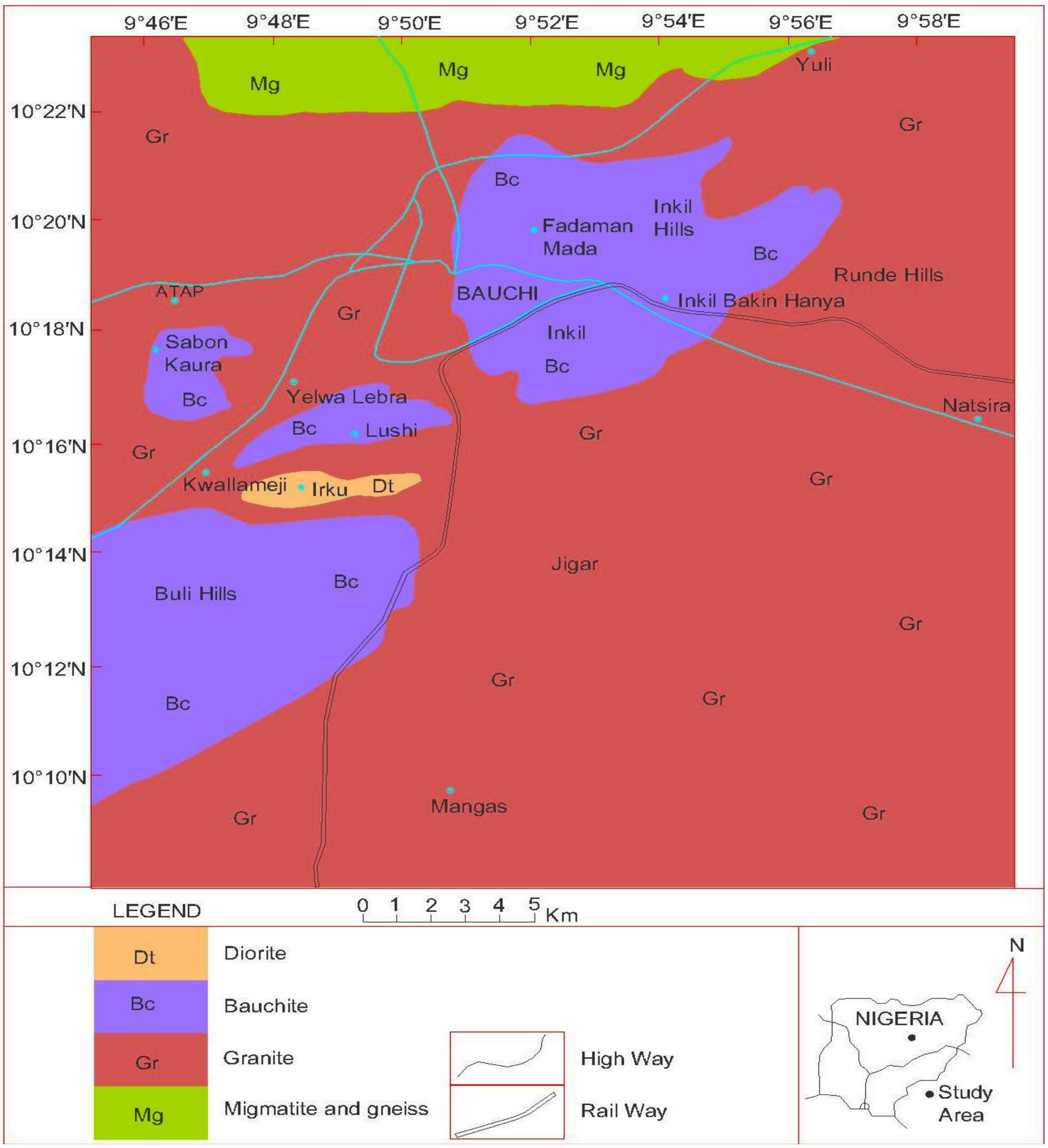

Figure-2
Geology of the Bauchi District (present work)

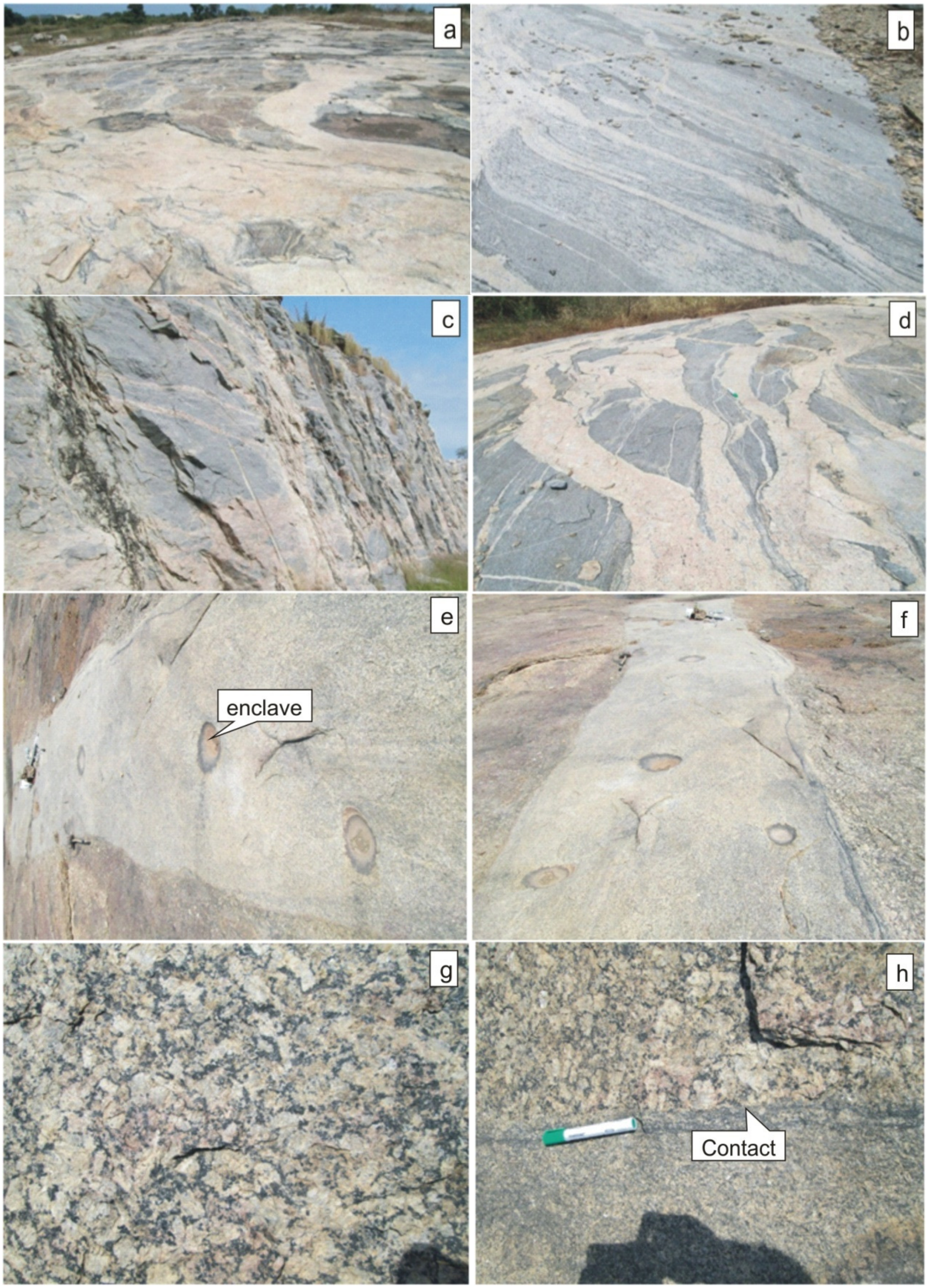

Figure-3

Lithology and field relationships of the granitoids of Bauchi district: a = migmatite, b = regular gneiss, c = aplite and pegmatite dykes, d = irregular gneiss, e = granite with enclaves, f = granitic dyke cuts across bauchite, g = bauchite, h = sharp contact relation between dyke and its host bauchite

Bauchite: Bauchite is the most distinctive of the rocks in Bauchi basement complex[7]. The rock is massive, hard, highly cemented and porphyritic with large microcline crystals (measuring about 5cm to 7cm) unevenly set in matrix of ferromagnesian minerals, quartz and plagioclase of approximate 1cm x 2cm across (Figure-3g). Fresh bauchite is typically dark green but turns brown on weathering.

In the field, bauchite appear texturally similar to the porphyritic granite except that it is dark green (when fresh), harder, more resistant and more cemented than the biotite hornblende granites which appear crushed especially when weathered. Weathered bauchite is even more difficult to differentiate from the granites as it appears brownish in colour similar to the grey to pink colour of the granites.

Bauchite occupy a SW – NE trending belt forming the most part of Buli hills in the southwest and occurring at Irku, Lushi and Yelwa to Fadam Mada and Inkil in the northeastern part (Figure-2). A variety of bauchite also occurs at Sabon Kaura but does not appear to extend to Jos road in the north. Here, the bauchite has sharp contact with highly weathered and eroded granite which appear as a dyke within the former. In each of these localities, the bauchite appear as large intrusive bodies into the most extensive and widely spread biotite hornblende granite. The contact between the bauchite and the granite is gradational. This transition is marked by a change in colour from dark green (where the bauchite is fresh) or dark brown (where it is weathered) to pink or grey in biotite hornblende granite. The gradual change in colour also coincide with a change in the mineralogy expressed by progressive decrease in fayalite, pyroxene (clino- and ortho-pyroxenes) and increase in biotite[10]. Eborall[11] attributed this mineralogical change to hydration reaction of water migrating from the granitic outer rock to the drier bauchite. This assertion is predicated on the fact that some amphiboles in the bauchite contain quartz blebs suggesting replacement of pyroxene during hydration. However, since such amphiboles are not confined to the contact zone, it may be due to reaction of water already in the rock and not necessarily from water migrating from the granitic outer rock to the bauchite.

Unlike the case of granite – gneiss contact where the granite may be fairly foliated in some places, there is no evidence of chilling or metamorphism at the contact between bauchite and biotite hornblende granite. Bauchite grades into biotite granites which gradually changes texture to porphyritic granites.

The bauchite close to the transition zone contain dykes of granitic materials ranging from 3m to 5m wide and 80m to over 100m in length. These dykes form sharp contacts with the host rock (Figure-3h).

Petrography: Because there exists detailed work available on the mineralogy of bauchite[6,12] a detailed discussion of this aspect is not included here.

Bauchite is composed essentially of microcline, plagioclase, quartz, pyroxene, hornblende with some accessory apatite, zircon and magnetite (Table-1). The microcline is commonly perthitic with subhedral to euhedral crystals characterized by sutured boundaries that host aggregates of other minerals such as quartz and feldspars. The plagioclase is oligoclase-andesine (Ab_{65} An_{35}) occurring in different sizes. It appears as irregular crystals but frequently as aggregates of smaller grains with twin planes having various orientations. Quartz is characteristically green with resinous luster and commonly occurs in myrmekite as vermicules and as small blebs included in other minerals[10]. Fayalite frequently occurs in clusters with other ferromagnesian minerals associated with quartz. The clusters are composed of iron oxide, hornblende and pyroxenes. The individual minerals do not appear to be secondary alteration products of other minerals but as primary minerals. Pyroxene is mostly found interlocked with fayalite while hornblende occurs as discrete crystals frequently associated with the fayalite. The granites are composed of microcline, plagioclase, biotite, hornblende, quartz with some accessory minerals. The microcline occurs as large crystals with perthitic structures and as small crystals without perthites. The plagioclase is generally clouded with alteration products. Biotite is generally more abundant occurring as irregular plates while hornblende usually occuring as overgrowth on the biotite. Migmatites and gneisses are similar in mineralogy both composing largely of plagioclase, biotite and quartz. The plagioclase appears crushed exhibiting poor twinning. The biotite is pale brownish in colour and pleochroic to dark brown. The quartz shows less crush features and exhibits strong undulatory extinction.

Table-1
Modal Composition of the Granitoids of Bauchi District

Mineral	Migmatite and gneiss	Granite	Bauchite
Quartz	18	23	24
Microcline	11	32	8
Plagioclase	30	23	14
Biotite	21	8	9
Hornblende	3	4	12
Pyroxene	4	-	12
Apatite	1	2	2
Zircon	1	2	1
Sphene	-	1	-
Magnetite	3	1	11
Opaques	8	4	7

Discussion: Minerals Paragenesis: Bauchite and the granites have similar mineralogy except for the significant abundance of mafic mineral phases in the former and their paucity in the latter (Table-1). Except for the extreme of abundant pyroxene and hornblende in the bauchite, the mineralogy of the granitoids of Bauchi and Zing-Monkin in Adamawa Massif are similar[13]. The mineralogy of the migmatites and gneisses appear to fall between that of the bauchite and granite. Consequently, paragenesis of minerals in the granitoids can be conveniently discussed in terms of the two rock units – bauchites and the granites.

In bauchite, hornblende, pyroxene and biotite are the major mafic minerals. Plagioclase and biotite are hosted by microcline. This shows that the latter post-dates both plagioclase and biotite. Quartz occurs interstitial to both plagioclase and microcline and as inclusions in microcline and biotite suggesting that crystallisation of quartz commenced at the same time as microcline and biotite but after significant plagioclase precipitation. The close association of apatite, sphene, zircon and magnetite with biotite shows that they probably appeared at the same time. The presence of zoned plagioclase in the bauchite indicates the presence of early ferromagnesian mineral, hornblende. The breakdown of such hornblende probably resulted to magnetite-apatite-zircon assemblage. In summary the sequence of crystallisation of minerals commenced with precipitation of ferromagnesian minerals + plagioclase. This early phase was followed by a more sodic plagioclase and probably zircon, sphene and apatite. Microcline and quartz are probably the last major phases to precipitate from the melt.

The other of precipitation of the minerals of the granites is similar to that described for the bauchites. Plagioclase which started precipitating early in the bauchite continued in the granite units increasingly becoming more sodic. Quartz, microcline and the accessory minerals crystallised later as the cooling of the magma continued. That microcline and quartz appeared late in the solidifying magma is buttressed by the replacement of oligoclase by microcline and quartz and the interstitial occurrence of the latter. In summary, the sequence of crystallisation of the various minerals phases of this unit is conveniently expressed in terms of early formed plagioclases and late assemblages of microcline, quartz and accessory apatite, zircon and sphene. Alteration of these minerals led to formation of secondary phases such as magnetite. The irregular outline and cloudy appearance of microcline crystals points to replacement as the dominant process in the generation of the observed textures.

Origin of the Granitoids: Granitoids are normally sourced from either the mantle, crust or both. While most granitic rocks originate by contribution from both, some are derived purely from the mantle or the crust[14,15]. The composition of the source and the physico-chemical processes that affect this source and the melt therefore control the chemistry of granitic rocks. Such chemical characteristics have been described by Pearce J.A.[15].

Chappell and White[16] recognised two types of granites (each related to a particular orogenic belt) – the I-type granite (which is compositionally expanded) and the S-type granite (which is compositionally restricted). Both granites have calc-alkaline characters and distinctive petrochemical characteristics which reflect the differences in the sources of the magmas. The I-type granites are derived from a basic igneous source by remelting of deep seated igneous material or the mantle, while the S-type granites are derived from melting of metesedimentary source materials. The fundamental distinguishing mineralogical and field characteristics of the different sources, as recognised by Chappell and White[16] are compared with those of Bauchi granitoids in Table-2. Such comparison shows that the granitoids of Bauchi district have I-type characteristics and support the model of its derivation by partial melting of basic source rock of mantle origin. The granitoids probably formed by partial melting of basic rocks (probably derived from igneous source) in the uppermost mantle and/or lower crust. As the magma made it way from the zone of generation to the sites of emplacement, it differentiated by progressive fractionation of hornblende, plagioclase, biotite, microcline, apatite and zircon leading to compositional and mineralogical variation from granites to bauchites.

The textural, mineralogical and field features of the observed enclaves in the investigated area are further evidences that the granitoids probably formed by partial melting of basic rocks of igneous origin in the uppermost mantle and/or lower crust. Mafic enclaves in granitoids have been variously documented[14,15,17]. According to El-Nisr et al.[17], enclaves (restites) that are indicative of partial melting of a basic source are often mafic in appearance, small in size, devoid of rapikivi texture and normally have gradational contacts with the host rock (similar to the mafic enclaves in the granites of Bauchi area). Didier[18] had earlier detailed the distinguishing features of the various enclaves in granites and the criteria for differentiating their various origins. Didier's features were later modified by Maurey et al.[19] who summarised the characteristics that distinguish enclaves of igneous from those of sedimentary origins. The workers also distinguish congeneric enclaves (cognate enclaves) from foreign (xenolithic enclaves) of igneous origin in the granitoids. Using the characteristics presented by these workers, the enclaves observed in the granitoids of Bauchi district are compared with enclaves of igneous and sedimentary origins in Table-3, and with congeneric and foreign enclaves in Table-4. From the Tables, it is clear that the textural, mineralogical and field features of enclaves in the granitoids of Bauchi district do not support xenolithic origin for the enclaves. The features appear to suggest that these enclaves represent remnants of igneous rocks connected with the source of the granitoids. They probably represent pre-existing rocks from which the granitoids of Bauchi district were derived.

Table-2
I- and S-type granite characteristics[16] compared with those of Bauchi Granitoids

Criteria	I-type	S-type	Bauchi Granitoids
Field	Massive, with little or no foliation. Contains mafic hornblende-bearing xenoliths	Usually foliated. Contains metasedimentary Xenoliths. May be associated with regional metamorphism; more likely to be found near their source and shows evidence (migmatite, regional metamorphism).	Except for the migmatite / gneiss, the granitoids bear little foliation. Contains Mafic enclaves in the biotite granite unit
Mineralogical	Hornblende and biotite + accessory magnetite	Muscovite + accessory ilmenite	Hornblende and biotite + accessory magnetite
Chemical	High oxygen fugacity, high Na_2O, > 3.5% in felsic rocks decreasing to > 2.2% in more mafic types.	Low oxygen fugacity, low Na_2O; normally <3.5% in rocks with approximately 5% K_2O decreasing to > 2.2% in rocks with approximately 2% K_2O.	NA*
Isotope	δ^{180} <10% SMOW $^{87}Sr/^{86}Sr$ = 0.704 - 0.706 $\delta^{34}S$ = 3.6 – 5.0%	δ^{180} >10% SMOW $^{87}Sr/^{86}Sr$ = >0.7061 $\delta^{34}S$ < - 5.00%	NA*
Ore Association	Porphyry copper, Mo	Tin	No porphyry copper, no Mo.

NA* = Not investigated

Table-3
Some distinguishing characteristics of enclaves of sedimentary and igneous origin in granites[18] compared with those of Bauchi District

Criteria	Enclaves of sedimentary rocks	Enclaves of igneous rocks (including meta-igneous rocks)	Enclaves in Bauchi Granitoids
Distribution	Concentrated about the periphery of the granite body	Concentrated centrally (if of congeneric origin)	Distributed randomly within the biotite granite units.
Texture	Perfect granoblastic (with banding sedimentary bedding) common	Variety of igneous rocks textures (and modification thereof) according to type; banding rare	Igneous texture with less directional fabric except for the gneisses.
Petrofabric analysis	Results comparable with those of the surrounding rocks	Results comparable to those of granites (if enclave is of congeneric origin)	NA*
Chemical composition	That of sedimentary rocks	That of igneous rocks	NA*
Shape	Tends towards angularity	Angular (if xenolithic in origin); Rounded (if congeneric in origin)	Shapes are varied ranging from sub-angular to sub-rounded
Zircon shape	Irregular or rounded edges and corners	Prismatic	NA*
Nature of plagioclase twin	Untwinned or very weakly twinned	Pronouncely twinned on various laws. Twin on 010 dominate over others. Abundant albite twin (if enclave is magnetic or thermally metamorphic)	Both twinned and untwined crystals present
Presence of large feldspar (phenocrysts or porphyroblasts)	Rare	Common	Observed in many enclaves

NA* = Not investigated

Sequence of Geological Events: Three broad lithological units were distinguished within the granitoids of Bauchi district. These include the migmatite/gneisses, the granites and the bauchites. This simple broad division based on lithology does not however reflect the range of complex relationships observed in the field. This complexity has however, been resolved in some areas but it did not allow for detailed correlation across the entire district.

The sequence of geological events (Table-5) that led to the emplacement of rocks in the district is not conclusive due to lack of geochemical data. However, it gives an insight into the evolution of the various broad divisions of the rocks. The earliest event probably involved crustal forming processes such as geosynclinals deposition and sedimentation closely followed by regional metamorphism leading to the formation of metasediments at about the Birimian period. Next came the Eburnean period during which reactivation of pre-existing rocks, deformation and migmatisation led to the formation of the migmatite and gneisses. This was probably followed by granitic intrusion, pegmatite and aplites development and high level magmatic activity during the Pan African period. The period is marked by the emplacement of the granites (both medium-grained and porphyritic) and the unusual bauchite in the complex. The late Pan African period witnessed the development of deformation resulting in faulting and dykes intrusions.

Table-4
Some distinguishing features of congeneric and xenolithic enclaves of igneous origin in intrusive granites[18] compared with those of Bauchi

Criteria	Enclaves of earlier and independently formed igneous rocks	Congeneric igneous enclaves = cognate enclaves	Enclaves in Bauchi Granitoids
Distribution	Particularly in proximity to country rock composed of earlier formed igneous rock	Throughout the pluton but with local concentrations where chilled margins or earlier dikes have been dislocated	Practically throughout the biotite granite units
Shape	Angular; sharp contacts with host granite	Rounded; diffused contacts with host granite	Sub-rounded; gradational contact with host rock
Texture	Metamorphic	Normal igneous	Igneous texture with directional fabrics in migmatite/gneiss units
Mineral composition	Independent of the granite. There is thermal disequilibrium between enclave and host; hence different mineralogy	Similar to that of granite. There is strong resemblance between minerals of enclaves and those of host granite evidence of thermal equilibrium	Mineral composition of enclaves very similar to that of host granite
Feldspathisation	Rare	Very common	Observed in many localities
Granitisation	Rare	Very common	Observed in many localities
Chemistry	Drastically different chemical composition from the host. There is no consanguinity between enclave and host.	Chemical composition deviates only very slightly from that of host. Tend to be slightly more basic than host.	NA*

NA* = Not investigated

Table-5
Generalised geochronology for the granitoids of Bauchi

Lithologic Unit	Probable Period/epoch (Ma)	Activity
Acidic and basic dykes	Late Pan African	Dyke intrusion. Period of alteration
Granites and Monzonite	Pan African (650±100)	Granitic intrusion, pegmatite and aplite development. Faulting and high level magmatic activity
Migmatite/gneiss (Banded gneiss, biotite gneiss)	Eburnean to Katangan (1900 – 800 ± 100)	Orogenesis: Reactivation of pre-existing rocks through deformation (e.g. faulting), acid rocks injection, widespread diffusion of Si, Na, K, and migmatisation
Metasediments (schists)	Birimian (2500)	Regional and to a lesser extent thermal metamorphism leading to recrystallisation. Crustal forming processes (e.g. geosynclinals deposition and sedimentation

Conclusion

Field mapping of the area at a scale of 1:50,000 shows that the area is underlain by three broad lithologic units viz: gneiss migmatite, granites and bauchite of various textures. These rocks are largely composed of hornblende, pyroxene, plagioclase, biotite, microcline, quartz with accessory apatite, zircon, sphene and magnetite. The rocks host enclaves of various shapes and sizes and are separated from one another by predominantly gradational contacts. The distribution of enclaves throughout the granitic unit, their sub-rounded shape and transitional contacts with the host rock are consistent with their igneous texture that the enclaves are syngenetic probably representing remnants of pre-existing rocks from which the granitoids were sourced. Interpretation of both the mafic enclaves and gradational contact relationships has led to a provisional conclusion that the granitoids are probably I-type genetically related to a common source by fractional crystallisation of hornblende, plagioclase, biotite, microcline and accessory apatite, zircon and sphene. Petrochemical studies similar to those of Greenough and Papezik[20], Oshin and Crocket[21], Lesher et al.,[22] are needed in order to assess more accurately the genetic relationships of the various rock units as the present study can only give an insight into this aspect.

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