PETROLOGY AND MINERALIZATION POTENTIALS OF THE NINGI CENTRE OF BURRA-NINGI RING COMPLEX BAUCHI STATE

BY

MALAMI ABDULKADIR USMAN

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All praises be to Allah, He Who taught the use of pen, taught man th that which he knew not.

I am indepted to my supervisor Mr. E. M. Shemang for having gone through the manuscript and given many valuable suggestions without which I would not have been able to do full justice to this work. I am also grateful to all those who offered me helpful suggestions in the course of this work. Especially, to Mr. U. F. M. Aniya whose thorough and thoroughful reading of the manuscript unearthed many implications.

My thanks goes to Aliyu Tukur Tahir, Usman Isa Liman, Ibrahim Bappah Waziri and Ahmed Abdullahi Bako who provided me with inspirations in ways they never realised. My friend Abdullahi M. Yami deserve me speacial thank for his valuable assistance and encouragements throughout our stay in the University.

I most sincerely thank my Brothers Ibrahim Sagir and Abdullahi Sagir for their assistance to my farmily in my absent.

And last but not in the least my wife Karima Abdulkadir for the d days and other ' rights ' she sacrificed.

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DEDICATIONS

This work is dedicated to the following for their worthy contributions towards the success of my academic career.

My Late mother	-	Hajiya Zulaihat Malami
My father	-	Alhaji Malami Masanawa
My step mother	-	Hajiya Rabi'at Malami
My Brothers	-	Alh. Tukur Malami and Shamsudeen Malami
My Sisters	-	Fatima Malami, Lubabatu Malami and Zainab Malami.

ABSTRACT

The study is made up of Ningi centre of Burra - Ningi complex of the Nigeria's younger Granite member and is located off Kano road about 110km from Bauchi between longitude 11°03 'E and 11°05 'E and latitude 9° 13 'N and 9° 34 'N.

The Ningi centre consists entirely of rhyolites, rhyolites porphyries, aegirine-riebeckite granite, Granite Porphyries and Basalts. The contacts between the different rock units are sharp and irregular suggesting that the units are distinct units with sequencial intrusins.

From field and Petrograhic study the Plutons are alkaline and Peralkaline and fit into the Syenogranite sub facies of the Nigeria Younger Granite of Bowden et al (1974).

The attempt to build an effective model for the evolution of Ningi centre of Burra - Ningi ring complex led to an exhautive discussions of already existing models on the Petro-genesis of the Younger Granites of Nigeria to which the study Plutons are member. These models range from derivation of the magma from mantle to derivation of magma from subsequent crustal contamination. Mc Dougall (1971) model of progressive diapiric intrusions of high temperature peridotite from within the low velocity zone into the lithosphere to explain the formation of the Hawaiian chain as well as models of derivation of the Younger Granite magma from the mantle with extensive crusal contamination proposed by sillitoe (1974) and the model of evolutionary sequence from gabbro through monzonite to syenite by contineous plagioclase and finally potassium feldspar fractionation to Peralkaline granite (McLeod et al 1957) were accepted from Ningi complex.

From the field evidence, there is no mineralization associated with rocks of the complex, but the rocks are extensively used as construction and building material.

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CHAPTER ONE

1 GENERAL INTRODUCTION

1.1 LOCATION AND ACCESSIBILITY

The study area is located along Bauchi - Kano road, about 110km from Bauchi. The Ningi centre of Burra - Ningi ring complex to which the extent of this work is restricted forms a prominent hill mass being topographically high relative to the s rrounding rocks. It is visible from the Bauchi - Kano road.

The area of study covers about $22km^2$ and extend from Ningi to Guda (southwest of Ningi) village. It lies between Longitute 11° 03 'E and 11°05 'E and latitude 9° 31 'N and 9° 34 'N. The mapped area forms part of sheet 106 Gwaram south west. The area was traverse by foot using the numerous foot path in the area and also the feeder road linking Guda with Ningi.

1.2 CLIMATE AND VEGETATION

The climate consists of two seasons - rainy and dry seasons, with the harmattan being a transition between them. The average annual maximum temperature is about $44^{\circ}C$ (Ningi local Government office) with hottest months of the year being March and April. The rainy season starts in early May and ends in September, whilst the dry season is from early October to late April. The mean annual rainfall is estimated to be 1300mm (Ningi Local Government Office).

The vegetation is Savannah type with decidious and thorny trees, short grasses and shrubs. During the rainy season vegetation is thick, but with the outset of dry season trees and shrubs wilt and rocks become better expose and more visible.

1.3 DRAINAGE AND TOPOGRAHY

The area is generally hilly, separated by an area of relatively flat ground through which the Ningi - Guda road passes. The larger part, about $40km^2$ west of Ningi - Guda road consists of a roughly oval mass of Younger

Granite. Areas devoid of rocks of Younger Granites are undulating and are underlain by Basement rocks. Topography of the hills appear to be almost entirely governed by the Northeast - South west jointly granites, along the line of which all the stream flow and dissection takes place (Jaque, 1948).

There is no major river flowing in the area, but seasonal tributeries of river Bunga flows East and Southeast of the mapped area.

1.4 SETTLEMENT AND LAND USE

The major settlements are Ningi, Tiffi and Guda. The major land use in the area is farming. The farmers practice both crop rotation and shifting cultivation. Farming is mainly done during rainy season and the main agricultural produce are millet, Maize, Guinea corn, Beans, Groundnuts and Cotton. Cattles and sheeps rearing is also common, mostly practice by the Fulanis and the inhabitants of the area respectively.

1.5 PREVIOUS WORK

The Burra - Ningi complex was first defined by Falconer (1911). He described it as a cross-cutting alkali granite containing biotite or riebeckite, characterised by chilled margin against their country rocks, he noted an underformed Post-tectonic character, contrasting it with the foliated Calc-alkaline Older Granite of the Basement.

Falconer and Raeburn (1926) surveyed and mapped the area. They considered the complex as rocky hill massits, sharfly differentiated from the smoother topography of the sorrounding Basement rocks. During this mapping it was found that the Burra - Ningi ring complex include many textural and compositional variations.

The first detailed mapping of the complex was made by Bain (1934), he showed that the structure is controlled by ring-shaped intrusions. Mac Leod et al (1952) showed the variation in granite texture and composition noted by earlier workers, usually occur as abrupt changes at igneous contact rather than transition within a body.

Bowden (1982) present a detailed reviewed thoughts on the Petrogenesis of the province. He showed that the alkaline lineage is depicted by rocks of monzonite to syenite composition and is controlled by plagioclase apatite, fayalite and clinopyroxene.

1.6 METHODOLOGY

A detailed mapping ofthe area on the scale of 1:25,000 was carriedout. Traverses across the area were made by foot, stop overs were made at stations where ever outcrops appears. Many trips were made to the Rhyolite and granite hills, during these trips adequate efforts were made to identify, trace and delineate all the rock types that make up the complex.

Fresh rock samples were collected, examined and observations recorded on both the map and in the field notebook. Contact zones and their associated geological features were studied.

Sample of rocks present on the ring complex body were collected. Eleven thin sections were made from twenty two representative samples. Among these eleven samples, one is riebeckite - aegirine granite, one basalt, four are varities of rhyolite porphyry.

In the laboratory, megascopic examination of the rock samples with hand lens to differentiate and identify the various mineral types which constitute the Phenocrysts or megacrysts was done. The megascopic examination was followed by microscopic work, during which form and crystallographic properties of the minerals were noted. Minerals were identified by their optical characteristics using standard procedures. Crystallization history of the rocks were unrevelled from textured relationship.

Conclusion on the mineralization potential within the rock units was drawn by studying the type of alteration and subsequent alteration products, fresh minerals were differentiated from the greisenized ones.

1.7 AIMS OF THE PROJECT

Although extensive geological survey and study of the Younger Granites rings complexes of Nigeria has been done, no detail work on the petrology, petrogenesis and mineralization potential of some of extended Younger Granite exposures like the Ningi hill granites which are parts of the Younger Granites has been carried out. Therefore the main aim of this project is to carry out a detailed field work, Petrographic and Petrological study of the Ningi centre of Burra - Ningi Younger Granite complex.

It is well known that Tin-mineralization is associated with the Nigerian Younger Granites. Ike et al (1984) and Bowden (1982) who worked on the area reported poor mineralization. This project thus also aspires to investigate the presence or absence of Tin-columbite mineralization in the granite suite.

There have been several hypothesis put forward by previous workers such as Jacobson et al (1958), Oyawoye (1968), and Bowden et al (1984) to explain the origin of magma of Nigerian Younger Granite. This research is also aimed at comparing and contrasting all the already proposed models and at determining the most suitable proposed models and to go further to develop one for the evalution of Ningi centre of Burra - Ningi ring comlex.

CHAPTER TWO

2 REGIONAL GEOLOGY

The rocks accuring in the study area are the Younger Granites consisting of Porphyitic Rhyolite, Riebeckite - aegirine granite, Basalts, Granite Porphry and Rhyolite Porphyry.

2.1 YOUNGER GRANITES

The Nigeria Younger Granite complexes are a suite of non-organic epizonal magmatic centres with over 50 units occupying a rectangular N - S province in central Nigeria (Turner, 1973). They were previously presumed to be differentiated from a parental magma of the composition of Pyroxene-fayalite syenite with two trends; one towards a Paralkaline and the other towards metaluminors rocks (Jacbbson et al 1958).

The Younger Granites are discordant high level intrusions which succeed the extensive acid valcanics and are emplaced by block subsidence. They commonly have clear topographic definition standing between 100m to 300m above the sorrounding Basement plain. They occupy a braod zone 400km N - S and about 150km wide between the 8th and 10th meridians. The form and general pattern of distribution of the ring centres may have been controlled by the pre-existing line of weakness in the pan-African Basement into which the complexes were intruded (Black and Girod, 1970). In general magmatism began in the North of the province in the mid-Jurrasic (170 ma) and ended in the late Jurrasic - early Cretaceous (140 ma) (Bowden and Van Breeman,. 1972). This N - S age trend is reflected in the overlapping of some ring complexes, a phenomenon attributed to the migration of magmatic foci due to mantle Plume traces (Van Breeman and Bowden 1973) or hot spots subsequent rifting in the Behue Trough. Various independent lines of evidence suggest that each centre of magmatic activity marked the intraction and development of a new separate magma chamber. Several cycles of intrusions and the overlapping and super position of the centre of intrusion (Bowden, 1979). A good example of this feature of ring complex is Burra -

Ningi complex which show a south westerly migration.

The evolution of the Younger Granite is quite complex. Any model to explain the origin of the Younger Granite need to account for: (Rahman and van Breeman 1984).

(1) Source of heat/or sudden release of pressure to produce melting.

(2) The distribution of ring centers along lineaments similar to recognizable structural pattern in the Basement Complex.

(3) The consistent sense of migration of ring centers along lineament.

(4) The shift of activity from one linearment to another.

(5) The petrological uniformity of the province.

Several models have been advaneed to explain the origin of linear belts of magmatic activity.Rhodes (I97I), applying the plume model of Wilson-(I963) and Morgan (I984) attributed the Nigeria Younger Granites to scar traces produce by the passage of lithospheric plates over a hot spot center on present day ascension Island. One of the main attraction of this model is that, its geometrical implications can be tested. For example, Vam Breeman and Bowden (I973) showed that the 0.7 - 0.8 cm yr^{-1} rate of southward migration of the Jurrasic Younger Granites was consistent with a lower Cretaceous opening of the Benue Trough and the South Atlantic in the RRE-RRR triple junction (Grant 1971 , Burke et al I97I).

Briden and Gass (I974) have slightly modified the plume model suggesting that sub-lithospheric heat sources are responsible for mid - plate magmatism only when focused for a long period on the same part of the lithosphere. Magmatic activity tends to be episodic rather than contineous. wilson (I96I) Ramsey and Graham (I970), and Durney and Ramsey (1973) have discussed the geometric forms and origin of en - echelon systems formed in shearzones. These models, and the dyke formation model of Pollard (1969) modified hot spot model of Vogt (I974), and the membrane tectonic model of Oxburgh and Turcotte (I974) predictes that magmatic activity would decrease in age in the direction of fracture propation and also explain why magmatic activity ceases along one fracture and move to another.

Mc Dougall (1971) proposed a model of progressive diapiric intrusions of high temperature peridotite from within the low activity zone into the lithosphere to explain the formation of the Hawaiian chain. He envisaged the high degree of partial melting along a propagating fracture in the moving lithosphere. A similar model has been proposed by Bowden (1973) explain the formation of Burra - Ningi complex.

Oyawoye (1976) has shown that the Younger Granite lies within a NE trending belt of granulite associated with high heat flow. Thus the formation of the Nigerian Paralkaline rocks can be explained by adopting the reaction melting theory of Berker et al (1975), 1976). This reaction melting model involves a multi-element process which reflect the interplay of a melt, formation of cummulates, partial melting of the country rocks and fractionation of cummulated melts. The partial melting of the country rocks occured via an energy input provided by heat librated during the formation of cummulates. As noted by Bowden (1970) the absence of contact metamorphism around the Younger Granite ring complexes suggest that the granite magma was emplaced into pre-heated country rocks. Thus less heat is required to initiate their melting and the volume of cummulates formed will be significally lower (Collerson 1982).

The high initial $^{87}Sr/^{86}Sr$ ratios exhibited by the paralkaline rocks may be interpreted to be the result of crustal contermination (Van Breeman et al, 1975). This contermination could have occured either by selective enrichment of ^{87}Sr via magmatic halogen rich fluids (Blaxland, 1976) or bulk assimilation of locally derived partial melts via a reaction melting -type mechanism (Barker et al 1975).

2.2 BURRA - NINGI RING COMPLEX

The ring complex is the largest in Nigeria and consist of six overlapping couldran or centres of mainly Rhyolitic ignimbrite and their feeder, displaced westward from Ningi (centre) to Burra (centre). The complex is rectangular in outline and form an isolated and prominent massif rising over 500m above the sorrounding Plain which range between 400m and 450m in altitude.

The ring complex intrude the late pre- cambrian to lower pleozoic basement rocks of Northern Nigeria in a N -S zone which continues north wards to the Air region of Niger Republic (Rahman 1984). This large branching ring dyke system consist of inner and outer ring dyke a few kilometres apart, jointed at interval by radial dykes of early volcanic rocks and late syenitic and granitic intrusions (Bowden 1979, Ike et al - 1982). The complex fallows a ENE —WSW age decrease trend characteristic of Nigeria Younger Granite. Bowden (1979) show the age of Burra - Ningi ring complex to be 180 ma, using $^{87}Sr/^{86}Sr$ ratio.

The Ningi ring complex under went two episode of magmatic activity characterised by the Nigeria Younger Granite, the volcanic cycle and plutonic cycle.

During the intial stage of volcanic cycle a considerable volume of lava and associated pyroclastic were erupted and the volcanic succession also include flows of basalt. The volcanism was accompanied by the formation of a large surface caldera in which the bulk of the effusive materials accumulated. Towards the end of the volcanic cycle a large plug of granite porphyry was amplaced in the centre of Ningi vent complex.

During the plutonic cycle one of the major structural feature of the complex, the peripheral ring - dyke of the aegirine-riebeckite granite was emplaced beneath the volcanic pile. Erision has priceeded to such a depth that all the major units of the cycle are exposed and this structural relationship can be clearly define.

In common with all volcanic ring - complexes in the Younger Granite province, the lavas are entirely confound within the peripheral ring -faults and they owe thus preservation at their preseny level to down faulting (Jacobson and MacLeod 1977).

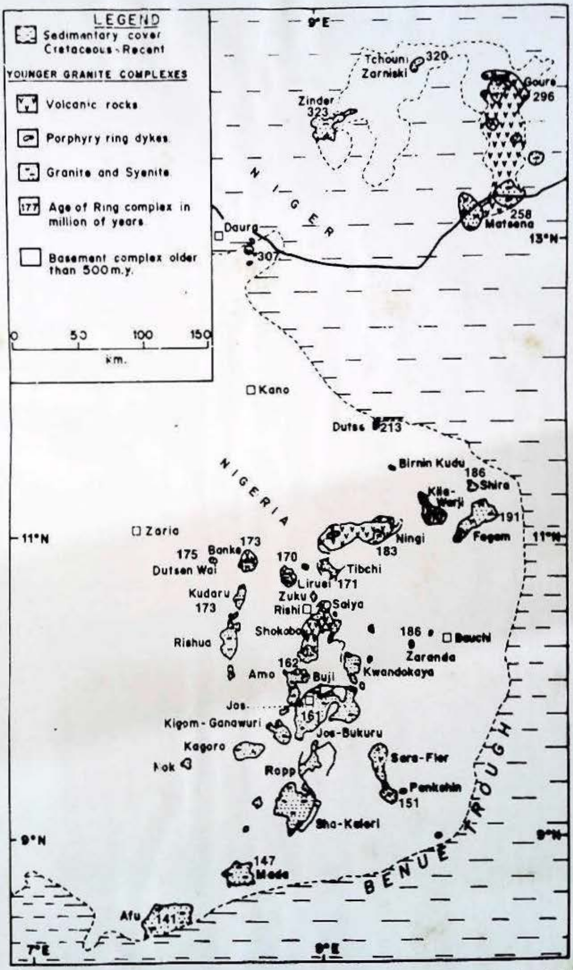

FIG. .—Map of the Younger Granite ring complexes of Nigeria and Niger showing their ages.

CHAPTER THREE

3 PETROLOGY OF THE ROCK UNITS

3.I INTRODUCTION

The study area forms part of Burra - Ningi Younger Granite ring com - plex, consisting of Rhyolites, Riebeckite - aegirine granite, Granite porphyry and Basalts.

3.2 THE RHYOLITES

3.2.1 FIELD RELATIONSHIP

The rock type covers about 75% of the mapped area. The rhyolites are marked by an arcuate vent structure running for about 4km around the easter n margin of Ningi centre and seems likely that the original volcanic land - form were broad sheild volcanos. The rhyolites are porphyritic showing extensive devitrication. Many irregular microcrystalline zones composed of tiny rounded grains of quartz and feldspar have poorly defined gradational boundaries. Most feldspar phenocryst are orthoclase, although phenocryst of plagioclase and quartz are present. Sanadine is the largest and the most abundant phenocryst, ranging up to 2mm in size. Quartz grain are rounded and embayed.

Granophyric texture of intergrown sanadine and quartz phynocrysts are common. The spherulitic groundmass exhibit strong flow banding with alterna- ting Iron oxide - poor and Iron oxide - rich layers. Devitrication of this spherulites of sanadine groudmass is chacterised by spherulites of sanadine and quarz that have nucleated around the phenocrysts . The mafic minerals are iron oxides and sparse spongy aggregates of amphiboles.

The rhyolites show some variation in colour and texture. According to Bain (I923), the vent appears to have provided a passage for a succession of eruptions whose surface flows have been subsequently removed by erosion.

This colour and textural variation was noticed as one move from Ningi to Guda

The rhyolites out crops have a regular sharp contact with all the rock units. They are associated with volcanic rocks such as Basalts at an axposure about 1.5km west of Ningi Emiros palace and at an outcrop 2km south of Tiffi. The rhyolites contains some inclusion of the country rocks with streaks of pagmatitic quartz and feldspar and their bands and their bands and lines of the dark minerals which mark the flow structures (fig 2).

3.2.2 PETROGRAPHY.

The Rhyolites are generally porphyritic. The development of porphyrit is texture depends on whether the magma body was completely extrusive and formed couldron or partly intrusive (oyawoye 1976).

The colour of the rock range from grey to black, and generally massiive and non - foliated. The phenocryst include potassium feldspar, plagioclasefeldspar and quarzt. The shaps of the phenocrysts range from ovoid to rectangular. The plagioclose are milky white, quarty grains are clear white to colorless and the potessium feldspard are pinkish with vitrous lustre. The phenocryst ranges in size from 2mm to 5mm and are embayed in a fine grained dark and dense groundmass whose mineralogy is megascopically undetermine. The groundmass contains some concretion of materials.

In thin section the minerals that formed the pherocryst comprises of orthoclase, oligoclase and quarts and small flakes of biotite.

Orthorclase forms about 40% of the total volume of the rock by visual estimation. The size range from 2mm to 5mm with subhedel to anhedral shape. The Cleavage is imperfect with a twinning according to carlsbad law. The orthoclose also form some fibrous acicular crystallites which are among the constituent of the spherulities (fig. 3).

The Plagioclase form about 81% of the volume of the rock. it is oligoclase (An 20 + 10) in composition measured using twin relation ship . The shape range from lcm to 3cm with a seriate boundaries (fig.3) sub-herdral to anhedrel with a albite twinning.

The quartz constitutes about 10% of the volume of the rock it occur as anhedral biparamidel grains of angular to subrounded shape. It show an undulose extinction under cross polars and clear under plane polarized light.

The biotite occur as small flokes scattared within the rock mass - it occupies abut 2% of the volume of the rock. It shows a strong pleochroism from reddish brown to green and dark green. The size ranges between o.5mm to 1.5mm. It has one directional cleavage and anhedral shape with usual parallel extinction.

The rhyolites has devitrifiied groundmass with microspherulitic texture and only occationally crystalline. Mineralogy probably as the that of the phenocrysts.

3.2.3 PARAGENESIS.

The sequeme of crystallization are based on the texture relationship of the minerals in the rock units. They followed the order of decreasing temperature, plagioclase crystallized at relatively high tempureture, the biotite, potassium feldspat (orthoclase) then quartz which crystallize at the same time with the potassium feldspars.

3.3 THE REEBECKITE - AEGIRINE GRANTITE.

3.3.1 FIELD RELATION SHIP.

This rock type covers about 15% of the total area mapped. The out crop is oval in shape about 1km long. It has a sharp but irregular boundary with the rhyolite, this can be located at Tiffi village. The rock unit is coarse grainid and milkly white with streaks of dark minerals.

3.3.2. PETROGRAPHY.

In hand speciman the granite is coarse grained. The minerals identifiable in megascopic examination are plagoiclase feldspar, quartz, and biotite The plagioclase feldspor is milkly white, the biotite is dark shining and us usual breaks off in flakes by finger nail scratching. The dark minerals are probably hournblede.

In thin section the plagioclase feldspar is oligoclase and by visual estamation it constitutes about 50% by volume of the rock and form clear subhedral plates showing albite twinning with a perfeet claevege and low relief. The oligoclase ($An_{10} - _{30}$) is coloulesss in thin section with a maximu extinction angle of 12° and weak birefringence.

Aegirine forms about 20% of the volume of the rock. It is green in thin section and strongly pleochroic with axial colour from dark green (x) to light green (Y) and yellow (2). They occur as long primatic cystal with a cleavage in two direction at angle of about 87° and 98°. The mineral is c characterised by a very light relief greater the balsom with strong birefringence and maximum extinction in logitudinal sections is very small (From 2° to 10°).

Quartz grain are round to elongated (Fig. 4) and constitute about 25% of the rock volume. The quarz is colorless in this section with a low relief and rather weak birefringence.

Riebeckite is filbrous in form and constitute about 3% of the volume of the rock. The mineral is characteised by a strong pleochoisin of deep blue (x) to light blue (Y) and greenish (2). The mineral shows a small distinetive extinanction angle with a high relief greater than balsam, a two direction cleavage at an angle of about 56° and 124° and a very weak birefringence.

Biotite is yellowish in thin section with euhedral crystals and a perfect cleavage in one direction.

. The mineral show pleocroism and strong birefringence and form about 1% of the valume of the rock. The biotite and the riebeckite are considér as accessary mineral in the rocks.

3.3.3 PARAGENESIS.

From the textural relationship the order crystellization of the mineral in the direction of decreasing tamperature. Hornblende crystallized first fallows by pyroxene and plagioclase which crystallized about the same time, then biotite and findly quartz crystallized.

3.4 GRANITE PORPHTRY

3.4.1 FIELD RELATIONSHIP

The granite porphyry occur south of Guda village at the extreme south-western part of the mapped area. It covers relatively small portion about 5% it is pink to brown in colour.

3.4.2 PETROGRAPHY

The granite porphyry is coarse grained with porphyritic texture. The mineral composition includes orthorclase feldspars, plagioclase feldspars quartz and the groundmass

The Phenocryst are mainly perthite and quartz. The groundmass or matrix is fine grain consisting of quartz feldspars and some iron minerals.

In thin section the orthoclase is microclune which is colourless with a Polysynthetic twinning in two direction, one according to albite law and the other according to periclune law. They form about 20% of the volume of the rock with a perfect cleavage and subhedral to anhedral in outline.

The plagioclase is Albite constituting about 3% of the volume tof the rock. They are blebs distributed through the microcline. The are characterised by a Polysynthetic twinning according to albite law. The relief is low with a rather weak birefringence.

The quartz constitute about 15% of the rock volume. The quartz is corroded ie the Phenocrysts of quartz are penetrated by lobes of the matrix. Some of the quartz are fractured indicating that they under went secondary alteration which result to secondary enlargement of the quartz Phenocrysts.

The matrix (groundmass) constitute the remaining 62% of the volume of the rock. It consists of quartz feldspar, iron-oxide and biotite flakes (plate 4)

3.4.3 PARAGENESIS

From the textural relationship the sequence of crystallization is in order of decrease in temperature. The Porphyritic texture of the rock units was developed by the rapid freezing of the remaining magma to form the matrix.

Plagioclase crystallized first together with biotite, follows by orthorclase feldspar and quartz which crystallized almost at the sametime.

3. 5 THE BASALTS.

3. 5. 1 FIELD RELATIONSHIP.

The basalts are fine grained and consists predominatly of plagioclasse and pyrocxene. In addition oliv ne and quartz a present. The rocks cover about 5% of the volume of rocks in the mapped area. Small insusire of basalts can be seen about 1km west of Ningi low cost house estate and another about 800m south of Tiffi. The basalts are characterised with versides occasionally found in the borde of the rlylite which it intrucded some of the vesicles (Cavities) notice were filled with olivine (amygdales). The shaped of the basalts is columnar. The basalts south of Tiffi village consists is columnar of olivine inclusions and hence named olivine basalts.

3. 5.2 PETROGRAPHY.

In hand specimes the rock is dark colored very fine. No any mineral recongnised in hand speciman, but in the outcrop south of Tiffi the basalts consists of olivine inclusion.

In thin section the plagioclase is oligoclase and usally lath-shape and well twinned according to carlsbal law with many inclution of glass It constitutes about 30% of the volume of the rock.

The pyroxene found are augites. They are characterised by their pale-greenish colour and absent of pleochroism. The augites occurred in two crystals with four sided cross section and a cleavage in two directions. The elief of the mineralsis high greater than balsam and moderate birefringence with a polysynthetic twins. It constitute about 10% of the volume of the rock.

Olivine constitute about 5% of the volume of the rock and about 30% in olivine basalt at Tiffi. The olivine phenocrysts at Tiffi are zoned, the outer zones are richer in iron than the core. The mineral, olivine is colourless in thin section and anhedral with polygonal outline. Cleavage is inperfect and irregularly fractured. Extinction is parallel to crystal outlines and cleavage traces with a fairly high relief.

The groundmass is made up of very fine minerals and constitute about ... lt and about 55% in the normal basalt.

3.5.3 PARAGENESIS

The order of crstallization fallows that of decreasig temperature. The first mineral to crystallized was olivine, then pyroxene and plagioclase begin to crystallize about the same time. Quartz crystallized last, although olivine and quartz are incompatible becouse if the composition of magms is such that quartz will crystallize, any early crystallized olivine is completetly resorbed if equilibrium is maintained. This rule is not likely to hold true with olivine that contain high content of iron minerals as the case of olivine basalt at Tiffi.

3.6 RHYOLITE PORPHYRRIS

3.6.I FIELD RELATIONSHIP

The rhyolite porphyries cover about 3% of the mapped area. The porphyries are porphyritic and domed shaped. The phenocryst are plagioclase feldspar and quartz with glassy groundmass. The rock units outcrops at Guda village with a sharp contact with the Granite porphyry to the south and a gradational boundary with the rholite to the west.

3.6.2 PETROGRAPHY

In hand specimen the minerals identifiable are quartz and plagioclase feldspar. The feldspars are milky white while the quartz are clear to colourless. The groundmass is glass.

In thin section the plagioclase feldspars are oligoclase characterised by the common Albite twinning, perfect cleavage and euhedral form. The oligoclase constitute about 30% of the volume of the rock.

Quartz constitute about 20% of the volume of the rock and have euhedral to subhedral form, some with inclution of the groundmass glass. Some of the quartz grains are fractured indicating that the quartz under went secondary alteration.

The groundmass by visiual estimation form about 50% of the volume of the rock. NO any minerals can be identified.

3.6.3 PARAGENESIS

The sequence of mineralization fallows the order of decrease in temperature. The first minerals to crystallize are the phenocrysts, in this case the plagioclase crystallized first fallows by quartz. Rapid chilling produced by injection of partly crystallized magma into fractures made the remaining matrix becomes glassy.

3.7 AREA OF MIXING

The area is of complex mixtures of mafic inclution and variously hybridized granitic rocks, the inclutions range from fine-grain, featureless basalt through various granitic rock types to ultramafic blocks. Inclutions ranges in size from a few millimeters to more than 5 centimeters and in shape from extremely angular to almost spherical. The edges of the blocks commonly show physical disintegration so that clouds of mafic grains and aggregates are strewn through the salic host, producing hybrid rock. The basalt appears to be chilled against the rhyolite, but both are very fine grained. The host rock remains unaltered suggesting that the dyke were altered by magmatic fluid accompanying this intrution or possibly by meteoric waters circulating along the emplacement planes during cooling. The composition of the intermeadiate rock from the dyke lies on straight mixingg lines between rhyolite rim and basalts core.

3.8 TEXTURAL AND MINERALOGICAL VARIATION

The rocks of the Ningi ring complex are alkaline to peraluminous and fit into the syenogranitite order of Bowden et al (1984). The textural and mineralogical variation in rocks of the complex are summerized in the table blow.

Table. I

ROCK UNIT	RHYOLITE	AEGIRINE-RIEBECKITE GRANITE	GRANITE PORPHYRY	RHYOLITE PORPHYRY	BASALTS
TEXTURES	SPHERULITIC & PORPHYRITIC	COARSE-MEDIUM GRAINED	PORPHYRITIC & FINE GRAINED	PORPHYRITIC, FINE TO GLASSY	
K-SPAR	40%	-	20%	30%	30%
PLAGIOCLASE FELDSPAR	8%	50%	3%	-	-
QUARTZ	IO%	25%	I5%	20%	-
BIOTITE	2%	I%	-	-	-
OLIVINE	-	-	-	-	5%-30%
PYROXENE	-	20%	-	-	IO%
HORNBLENDE	-	3%	-	-	-
ACCESSORY	UNDETERMINED	I%	62%	50%	30%-55%

CHAPTER FOUR

4 PETROGENESIS OF NINGI - BURRA YOUNGER GRANITE RING COMPLEX

This chapter attemps to discuss the relationship between the different rock units in their evolution and also the relationship between the Ningi complex. It is also aimed in building a model of evolution for the granite suite and compare and contrast this model with the existing models put forward for the evolution of the Younger Granites of Nigeria of which this suite is a member. The merits and demerits of each model will be analysed and finally a suggested model will be developed for the study area.

The rocks of Ningi complex are similar to those obtainable from Younger Granite complexes which indicates a probable crystallization from magma of related origin. Black (1955) has demonstrated that the Younger Granites have uniformity in composition, mineralogically and chemically

Various attempts at solving the question of the origin of the non-orogenic granites in Nigeria have been expressed by many authors, and these arguments can be applicable to Ningi complex. Jacobson et al (1958) proposed that the fayalite-pyroxene syenite magma is the one from which other rocks of the Younger Granites are differentiated. They based their conclution on the sequence of intrusions found in Younger Granite provinces in Africa. The order is syenite first, fallowed by hornblende biotite granite to riebekite granite and lastly albite-riebeckite granite. It was further demonstrated by Jacobson et al (1958) that the chemical variation pattern of these rocks means that the sequence of intrusion is in the direction of increasing soda and silica content. However, Oyawoye (1968) argued against this conclution he stated that the fact that the samples they analysed were too few. Another objection to the above conclution is the reverse intrusion sequence that have been observed in some granite complexes (Turner 1963) beginning with biotite granite first and ending with syenite.

Black (I958) suggested differentiation based upon crystal fractionation and showed that biotite granite can be derive from hornblende-fayalite granite by the removal of early formed alkali feldspar, fayalite and pyroxene at high temperature. To obtain riebeckite granite from the same rock (parent) it is necessary to remove more alumina than that combining with an equal amount of alkali feldspar. Black also proposed that this was effected by the crystallization of hornblende taking place at low temperature. This assumption was butteressed by the crystallization of mafic minerals which were observed to have crystallized in the order of the discontinous reaction series and the early settling out of fayalite and pyroxene can be correlated with chemical changes that affected the rock.

In the study area all the various rock units have sharp boundaries, for instance the boundary or contact between the rhyolite and the riebeckite-aegirine granite exposed at Tiffi village is sharp. Also the contact between the granite porohyry and the rhyolite body at Guda village is sharp. This sharp contact between rock units serve as an evidence of sequencial intrution. Therefore, this indicated that the rock units did not crystallized from the same magma body intruding the Basement.

Oyawoye (I956) using Turtle and Bowden (I928) model of derivation of granite from crustal rocks that contain SiO_2 , Ab, Or and H_2O by melting, drew attention to the possibility that the magma of the Younger Granites originated by melting of the rocks of the basement complex. He argued that since biotite hornblende granite and granodiorite (older Granite), fayalite bearing granite and quart monzonite are wide spread in the Nigerian Basement, the fayalite bearing rocks of Nigerian Younger Granite could have resulted from the melting of these rocks. He also said that, the amphibole granite magma could have originated from melting of the wide spread porphyroblastic older Granite. This model however, does not explain the origin of the paralkeline granite member of the Younger Granite. Also Macleod et al (I97I) pointed out that although Basement complex has some geochemical features in common with the Younger Granite such as high Sn and Tb content, the difference in content of most elements must be considerable. According to Macleod et al (I97I) The fusion of the Basement rocks would produce large volume of liquid of low melting composition in the quart- alkalin felds per system, and it seems unlikely that such an origin could result in the geochemical distinctiveness or the high degree of homogenity over large areas that characterises the Younger Granite.

Recent work by Leake(I979) support generation of granite magma by crustal melting. He substantiated his assertion by saying firstly, that there is no subtantial part of continental part of continental crust that is devoid of granite intusion suggesting derivation of granitic magma from melting of continental crust. Secondly for granitic magma to be emplaced at upper crust, the condition of melting must be almost anhydrous with water being derived from melting of mica and hornblede which are only available at the crust. Turner and Bowden (I974) suggested that non-peralkaline granites may have developed in the lower crust due to crustal arching, volatile concentrations and heat focussing, but the peralkaline granite could also be of crustal arigin developed by contact anatexis during the limited phase of basaltic magma eruption. Bowden (I970) suggested that peralkaline and non-peralkaline granite could be generated in the upper crust by progressive melting of granitic basement rocks. He based his argument by considering the enriched traced element concentration and the limited Isotopic evidence The wide variation in initial $^{87}Sr/^{86}Sr$ ratio exhibited by the Nigerian Younger Granite, (Bowden and Van Breeman I975) has been used as an argument in favour of significant contribution of crustal rocks in the genesis of these granite complexes. They high strontium ratio may be interpreted to be the result of crustal contermination and crustal melting. This contermination could have occured either by ... ^{87}Sr via magmatic halogen rich fluids (Blaxland-

1976) or bulk assimilation of locally derived partial melts via a reaction melting-type mechanism (Barker et al 1975, 1976). Ferrara and Trevil (1974) argured that , this variation in initial Strontium Isotopic compotion which increase in fractionation can occur during protracted fractional crystallization.

Bowden (1928) discussed the origin of granitic magma as end product of the differentiation process of an original basic magma. But based on the extensiveness of these granites, large volume of basic magma are required to form the granite (Orazulike 1986). The independent nature of the of the magma chamber of each complex in the Nigerian Younger Granite province (Turner), the very small proportion of gabboroic rocks associated with the complexes (MacLeod 1963) and the small amount of water in the upper mantle, about 0.1% (Allegro 1976), have been used as against mantle origin of granitic magma. MacLeod et al (1971) emphasised that, if these rocks were differentiated from basic magma, one would expect far more common occurance as diorite and other rocks of intermediate composition between gabbro and granite in the younger granite province and the other rocks would be far more diversified from complex to complex

Recently unpublished review of the geochemical work of the Nigeria Younger Granite Province (Bennet et al 1981) on the basis of 300 whole rock analysis, show rapid decline in TiO_2, total iron and MgO. This could be as a result of fractional removal of olivine and titano-magnetite, fallowed by augite and plagioclase since in the early stage the decrease in Cao is more marked than Al_2O_3. This evidence together with the asso-ciation of syenite and peralkaline granite at Ningi complex suggest an evolutionary sequence from gabbro through Monzonite to syenite and by cont-neous plagioclase and finally potassium feldspar fractionation to peralkaline (Villens 1974). The hypothesis therefore concluded that the genesis of gabbro, anorthosite, monzonite, syenite and peralkaline gra-nites and volcanics in Nigeria appear to have been via prolonged fractional ... while the biotite and hornblende indirect result of the former process by partial fussion of the crust.

McDougall (I97I) proposed a model of progressive diapiric intrusions of high temperature peridotite from within the low velocity zone into the lithosphere to explain the formation of the Hawaiian chain. He envisaged the high degree of partial melting along a propagating fracture in the moving lithosphere. A similar model has been proposed by Bowden (I973) to explain the origin of Ningi-Burra complex.

Sillitoe (I974) proposed mantle origin for the Younger Granite. He showed that Sn mineralization can be explain with refrence to mantle sours for the host granite rocks. He related the genesis of Younger Granite to hot spot activities. His contribution solves theenigma of high Strontium Isotope ratio in the Younger Granite.

Wright et al (I985) said that the magma must have been generated by partial melting in the upper mantle and lower crust beneath the crustal domes into which the completes were emplaced. Isotopic data according to them imply significant crustal involvement in the genesis of the magma. They went further to assert that crustal melting may have been facilitated by volatile fluxing from the upper mantle. As mantle derived magma in a continental hot spot environment will undergo extensive contamination. Crustal fractionation may also have occurred to contribute to the diverging peraluminous geochemical trends. They also said that the distribution patterns of rare-earth elements in some peralkaline granites chiefly suggesst a strong europium (EU) deplation, are consistent with precipitation of early plagioclase feldspar and with crystallization of late alkali-bearing amphiboles from volatile-rich low temperature fluids. He further asserted that the fayalite and pyroxene bearing porphyries and related rhyolites solidified from comparatively anhydrous magmas that could have mainly come from lower crust.

The rock units in the study area as has been earlier said are distintive with a sharp boundaries. Therefore the idea of one unit evolving from the other is unlikely, becouse of the sharp boundaries . In Ningi complex , from the relationship envisaged the first surge of magma is mainly rhyolitic that obeyed the general law of rhyolite formation during solidification. This is fallowed by purely granitic magma. The boundaries between the rhyolite and the intruding basalt is also sharp indicating emplacement from different magma body to that of rhyolite. Field and petrological data on Ningi complex suggest an evolutin trends assuggested by Bronw(I98I) for most granites. These are sharp boundaries between the differentb rock units which make them dirtinct and suggest successive intrusions. Therefore based on the above features of the rock units as well as distinct characteristic the rocks of the study area could be said to have mantle origin as suggested by Sillitoe (I974) with extensive contamination by crustal materials during the course of evolutionary extrusion and intrusion as proposed by Wright et al (I985). Although no chemical analyses was carried out in this study, field relationship, mineralogy and texture of the different rock units suggest that they belong to the alkaline-peralkaline types of S-tupe granites.

CHAPTER FIVE

5 ECONOMIC GEOLOGY

5.I MINERALIZATION POTENTIAL OF NINGI COMPLEX.

The Nigerian Younger Granite ring complex to which the Ningi granite complex belong are among those magmatic metallogenic province where there are a number of genetic type of primary mineralization linked with the same period of magmatic activity, The number of elements of possible economic sigficance is also relatively large. The most important are Tin, Niobium, Tungsten, Molybdenum, Zinc, Lead Cadmium, Silver, Copper, Bismuth and Lithium

There are a number of factors which effect the development of economic mineralization in alkaline granite complex. These include the source origin of magma generation, the influence and composition of continental crust, and the role of fluids which scaverge and pericitated the ore metals in high concentration. The primary mineralization is almost exclusively to the biotite granite as dissemination in albitised granite and as greissen lodes and vein. Geochemical and mineralogical evidence suggest that the magmas from which the the granite formed were derived by partial melting of crustal source material. They are commonly peralkaline and show characteristic of S-type granite. It was suggested by Bowden (I976) that Tin and associated elements were concentrated by process of fractional crystallization and fluid phase transfer. Some of the minerals are presently being exploited on the Jos plateau as placer deposites. Bowden (I976) pointed out that the original granite has been locally connected to albite, microcline and grisen

Though mineralization in Nigerian Younger Granite Complex has been established no such mineralization is recognise in rocks of Ningi complex.

The rhyolites which are the dominant rock units in the mapped area are considered to be associated with mineralization world wide. For instance the Uranium deposit of Utah (Steven and Ramasson I982) where hydroth[illegible] Uranium mineralisation occurance is genetically associated with emplacement of glassy rhyolite dyke. According to these authors the rhyolite-basalt dyky, and Uramium and Molybdenum bearing vein from a related hydrothermal system formed in fractures in the highly broken roof above the stock. The low grade Ore dassemination of copper, iron and molybdenum in the volcanic envelop of Linga unit of Peruvial coastal Batholith of Zambia give another case study (Agar 198I). In the Nigerian Younger Granite, many mineral dassemination have been demonstrated at Tibchi (Bowden I976) Also flourite, sulphite and quartz sulphite vein deposite do occur as a result of fluid interaction with the volcanic cover.

The thin section study of rhyolite frim Ningi does not indicate any presence of sulphite in the rock, though grinsenization are noted at contact and fissure of the rock units notably rebiekite-aegirine granite, but this is not very much pronounce. Further more, where as hydrothermal Ore deposit indicate presence of Ore bearing fluid , evidence of hydrothermal activity is not the only diagnostic evidence for mineralization, this is becouse of other factors that operate in conbination with the hydrothermal fluids to make mineralization process. These factors include the trace element content and in this case the tin content of the fluid, the salinity and acidity of the fluid, the source and dgree of interaction of the fluid including ion excha nge and also the tempetature of formation of the griesen as well as the structural or stratigraphic factors. In Ningi the mineral of Ore value may have accompanied the rhyolite part of plutonism but have been eroded away judging from the intensive erosion of the area. Kinnaird (I979) showed that, in the anorogenic ring complex, a series of hydrothermal alkaline process with related mineralization can be recognised. In peralkaline granite, the process of sodic metasomatism is characterised by the development of albite, aegirine and alkaline amphibolein the compositional range from riebickite to lithium erfvedsonite as in the case of riebekite-aegirine granite of Ningi. The riebekite and aegirine are optically distinguished by a deep blue to brown colour and is characterised by high total iron. The high concentration of some of the minor elements in the riebekite-aegirine granite has lead to the suggestion that the later may represent pegmatitic intrusion or at least that the granite have been altered by hydrothermal fluids.

Bowden (I982) and Wright et al (I985) established a series of age migration from NE - SW with the Northwards Younger Granites being older than the Southwards Younger Granites. The subsequent migration of orogenic center which gave rise to local cocentration of columbite, casseterite and Uranium was linked to the age, magma type and fractionation. From their view the younger magma of the South are more enriched with minerals forming trace elements than the Older magma, since the Northern younger granites are unmineralized. Olade (I980) suggested that part of the reason for non-mineralization of other rock units in the Younger Granite Complexes is due to the fact that tin is locked up in riebekite, fayalite and hornblende minerals which crtstallized early in the paragenetic sequence.

Alluvian and Superficial deposits along the stream channels under close examination could not yield any positive result for Ore deposition or sulphite dissemination. Therefore if Ningi complex have some mineral dassemination it would have been eroded and deposited very close or far away from the complex.

CHAPTER SIX

SUMMARY AND CONCLUTIONS.

The mapped area is made up of five rocks units, The rhyolitics, aegirine - riebeekite granite, granite porphyry, rhyolite porphyry and Basalts

The field relationship and petrographic study indicate that the rhyolites of Ningi complex have porphyritic textures with the spherulitid textures and the mineralogy comprises of orthoclase (40%) Oligoclase (8%), quartz(10%) and biotite (2%). The accessory minerals are undetermine which are probably the same with that of the pherorypt. The aegirine-riebeekite granite, coarse grainal with a porphyritic texture. The minerals identifiable are oligoclase (50%), aegirine (20%), quartz (25%), Riebeekite (4%) and biotite (2 %) for the accessory minerals. Granite porphyry has porphyritic texture and has incrochine(20%), quartz(25%), biotite(3%) and the matrix(62%). Rhyolite porphyry in porphyritic in texture and the minerals are oligoclase(30%), quartz(20%) and ground mass(50%) consisting of quartz and feldspars. Basalts are fine grained rocks with some vesichles and inclusion in some, the minerals recognised are Oligoclase(30%) Pyroxene(10%), olivine(5%) in the fine graind type and (30%) in the olivine basalts and glass (40%) in the fine grain basalts and (55%) in the Olivine basalts.

From the petrologic and field relationship study, the Ningi ring complex is similar to those of the central Plateau of Jos. Hence, mantle origin for those rocks has been suggested with crustal contamination as proposed by Silititoc (1974) and supported by Brown (1958) and Wright et al (1968). Their evidence include the sharpness of theboundaries. Also an evolutionary sequence from gabbro through monzonite to syenite by contineous plagioclase and finally potassium feldspar fractionation to peralkaline granite granite (Macleod et al 1957) can also be suggested for the Ningi complex.

This work is restricted to the petrographic study ofthe rocks and field relationships. Due to this restriction, most of the petrochemical deduction onthe genesis of the Ningi complex as well as the tectonic and structural evolution models of various rock emplacement mentional above were based on inferred data. However, in order to obtain more information as regards to the origin of the magma of the Ningi ring complex, analysis of the rock units is necessary.

Because of the aforementioned limitations, it is suggested that further research which will employ both geophysical and geochemical methods on the rock units is required. And this should fallow two approaches, the field approach. Geophysical study may be limited mainly to gravity and magnetic survey to know the vertical thickness of the exposure. The anomaly shown by the the magnetic and gravity survey will also help to determine if these dissemination of Tin or Sulphide deposits covered by the rhyolite cover

Laboratory work on the various rock units of Ningi ring complex should include chemical analysis for percentage oxide of the metals contain in the rocks and also isotope geochemical studies of the rock minerals and the greisen. This will give metal oxides which will be plotted on a Harker diagram whose data clustering will indicate the variation in the oxides with respect to SiO_2. The percentage oxide can also be plotted on an AFM diagram (A= Na_2O, F Feo: Fe_2O_3 Total iron and M=Mgo) to know the compotional variation of oxide in the trend. All this will help to tell the amount of oxide in the rocks and the rock type. The Isotopic studies will help to find the age of the rock andthe temperature of formation of both study will also give indications of sulphide or other orepotential of the rock. Detailed chemical studies could reveal the presence of some rare metals in trace or minor amounts in the rocks,

LIST OF PLATES

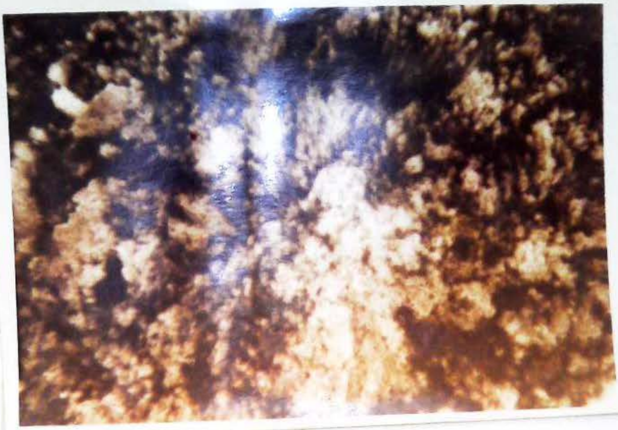

PLATE. 1

Photomicrograph of rhyolite showing feldspar spherulites. Under cross nicol x 40

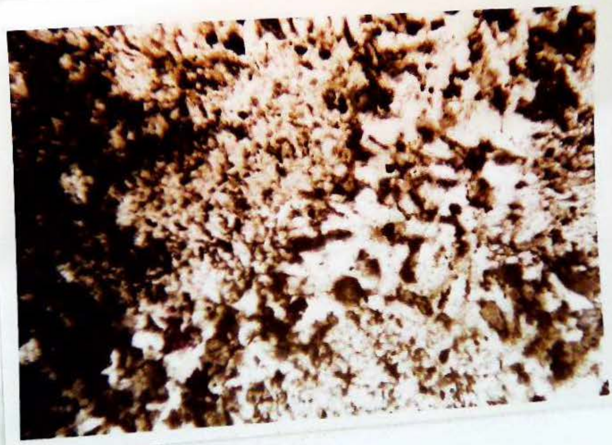

PLATE. 2

Photomicrograph of rhyolite showing bandig cause by flowage.

PLATE. 3

Photomicrograph of aegirine- riebeckite granite showing aegirine and riebeckite grains (Pink and green colours). Under cross nicel x 40

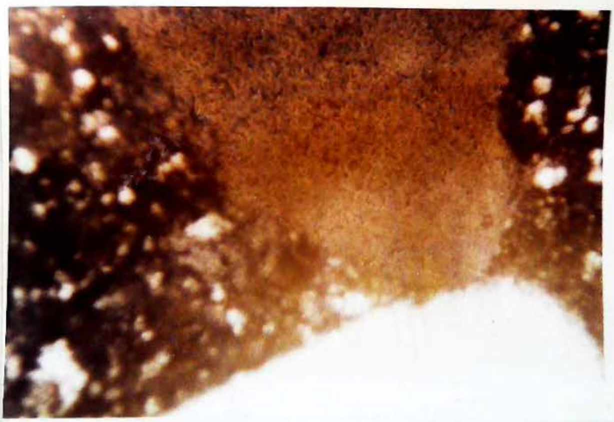

PLATE. 4

Photomicrograph of granite porphyry showing carlsbad tw twinning in orthoclase feldspar. Under cross nicol

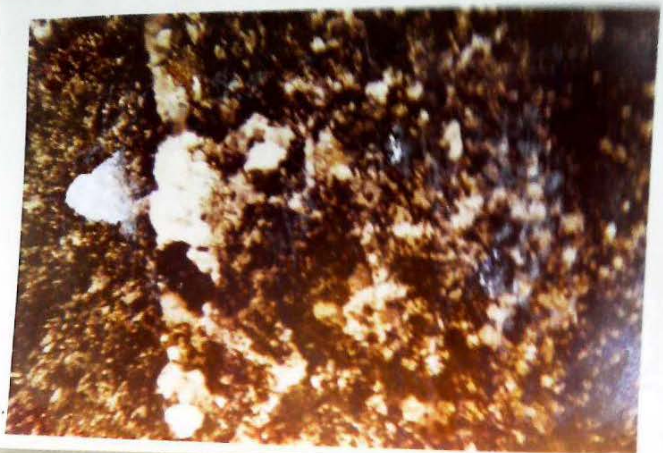

PLATE. 5

Photomicrograph of basalt showing **fine** grained texture with some olivine inclusions. Under cross nicel x 40

PLATE 6

PLATE. 7

Photomicrograph of rhyolite porphyry showing Albite twinning and quartz intergrowth. Under cross nicel x 40

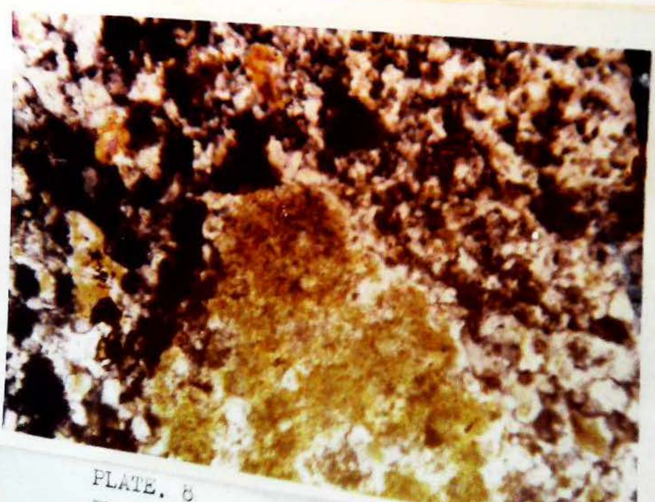

PLATE. 8

Photomicrograph of the rocks from area of mixin[illegible] showing granite phenocryst and othen [illegible]

Under cross nicel x 40

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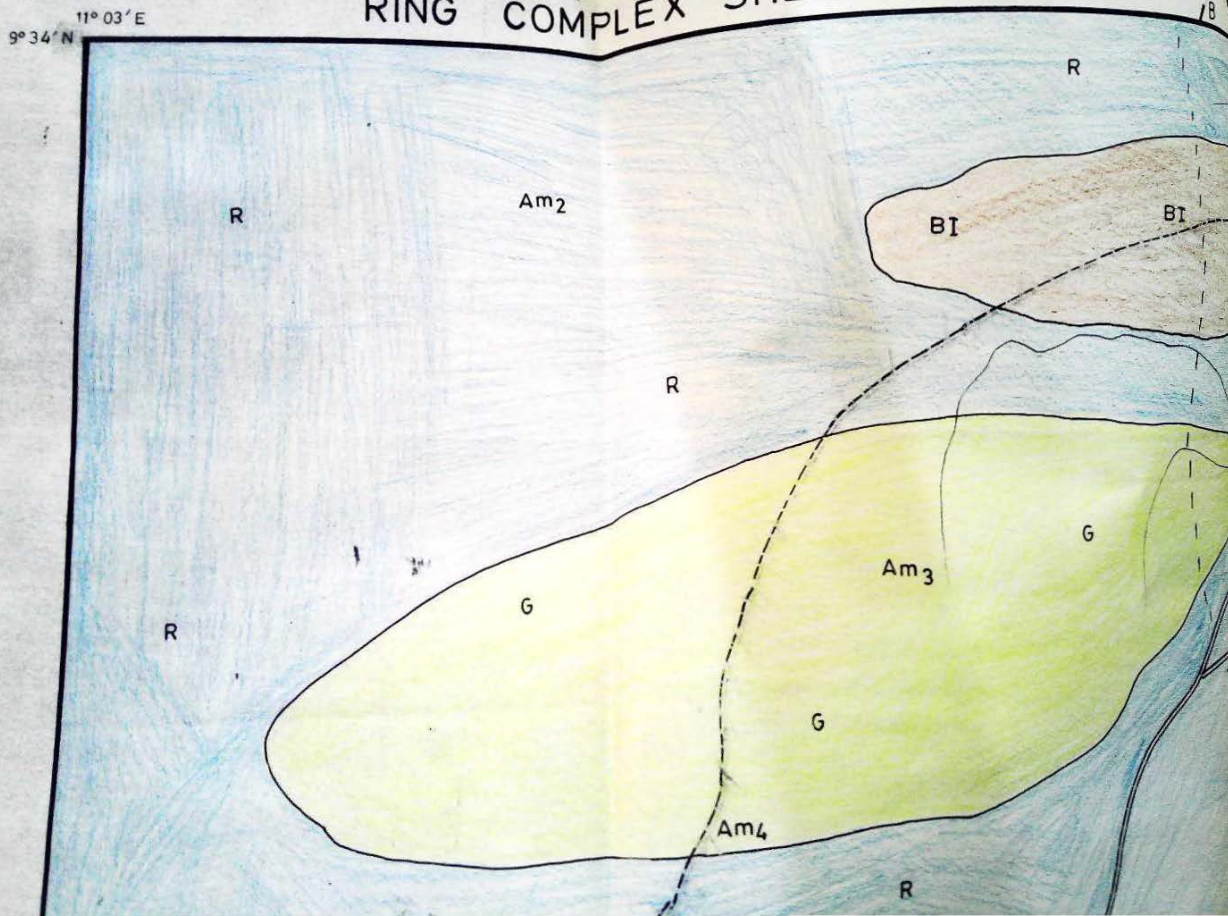
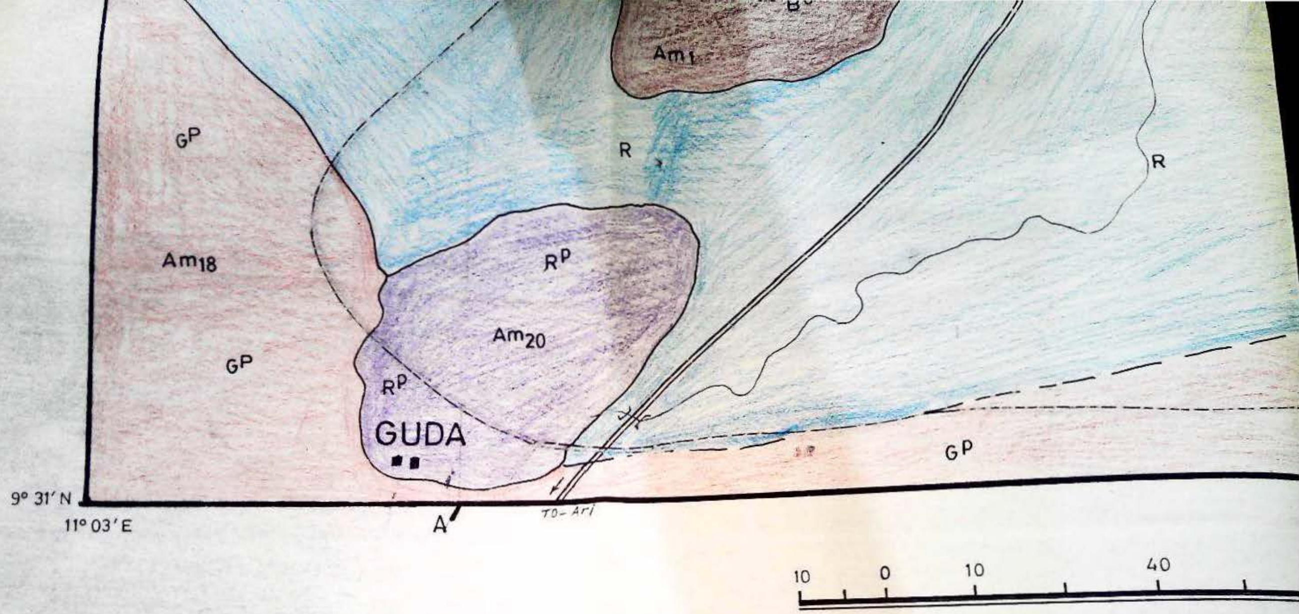
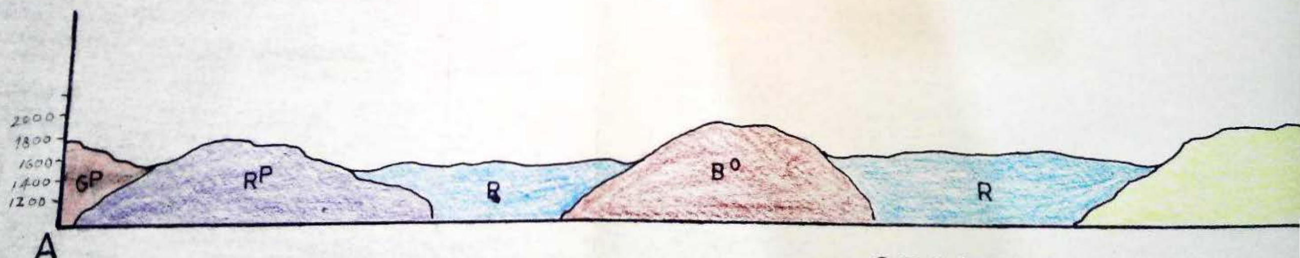
Fig.1 GEOLOGICAL MAP OF NINGI CENTRE OF BURRA-RING COMPLEX SHEET 106 S.W.

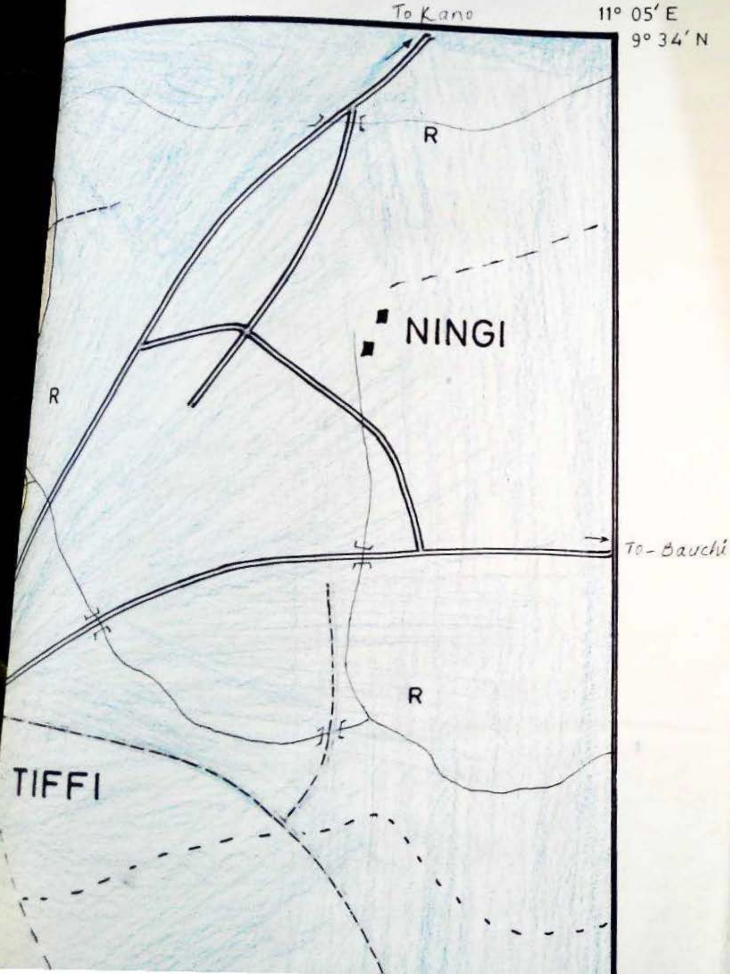






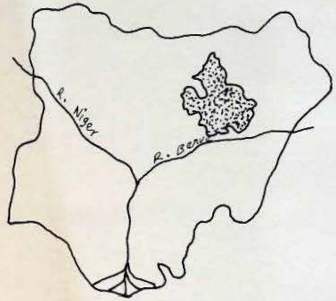
CROSS SECTION A

NGI



MAP OF NIGERIA SHOWING THE LOCATION OF BAUCHI STATE

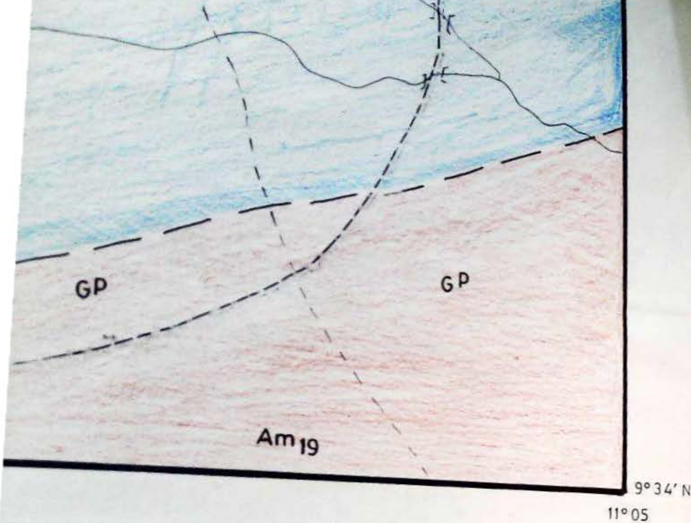
Fig. 2



MAP OF BAUCHI STATE SHOWING THE STUDY AREA

Fig. 3

KEY



BI Basalt

Bo Olivine Basalt

Streams

Am3 Selected Sample Location

Geological boundary certain

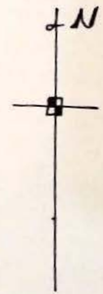
Geological boundary inferred

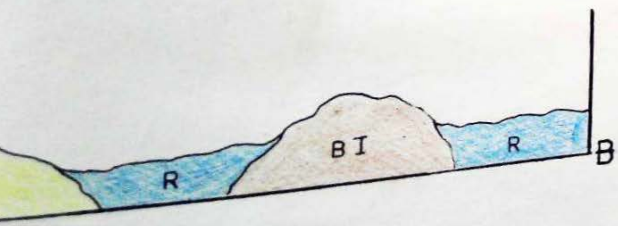
Major roads

Minor roads

Minor paths

G, R[P] Rock symbol





Mapped by Malami Abdulkadir July, 1991.