A REVIEW OF THE STRUCTURE AND PETROLOGY OF THE KUDARU RING COMPLEX.

A THESIS SUBMITTED TO THE DEPARTMENT OF GEOLOGY, AHMADU BELLO UNIVERSITY, ZARIA, AS PARTIAL FULFILMENT FOR THE AWARD OF A BACHELOR OF SCIENCE DEGREE IN GEOLOGY.

BY

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To My Family

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A B S T R A C T

The geological map of Kudaru complex has a characteristically elliptical ring-dyke structure already described by earlier workers. Hocks on this complex consist mostly of alkali granites and their subvolcanic and volcanic equivalents. The major rock types ares Quartz porphyry, granite porphyry, fayalita granite, Biotite and Biotite granite and rhyolites.

Contrary to the assumption that the ring dyke is made up of one rock type, it has been confirmed in the field and on the microscope that the ring dyke is made up of two rock types namely the quartz porphyry and the granite porphyry.

The cone-sheets can be divided into three major petrological units?

- The granite porphyry
- Fine grained riebeckite granite
- Rhyolite.

The southward displacement of the 'central[1] pluton beyond the confines of the ring-dyke has important implications which include:

1. A southward shift in the centre of magmatic activities analogous to the already well documented migration of ring-complexes in the Niger-Nigeria Younger Granite Province.

2. Hydrothermal alteration of the rock (notably the granite porphyry ring dyke) in contact with the displaced granite.

The presence of extrusive volcanic rock is reported by the writer and its apparently small size is most probably a result of erosional activity which must have eroded a large portion of the rock during geological time. The presence of this rock also helps to suggest that the ring dyke was emplaced by the process of surface cauldron subsidence, a process which Bain (1934) was unable to suggest.

CHAPTER ONE

INTRODUCTION

1.1 GENERAL STATEMENT

The Kudaru complex (fig. 1a) was the first to be recognised as a ring structure in the Nigerian younger granite province and it was in this complex that the first fayalite - bearing granite in Nigeria was discovered (Bain, 1934). The Kndaru complex therefore has a unique significance in the history of the study of the Nigerian younger granite complexes.

1.2 AIM OF STUDY AND SCOPE OF WORK

A I M: The aim of this study is to review, within a limited scope, the study of the structure and petrology of the Kudaru complex in the light of more recent findings in some of its neighbouring complexes.

It has become desirable to make this review since to the best of the knowledge of the writer, the last published study of the complex (including the geological map) was made forty six years ago, by Bain (1934).

S C O P E The scope of the present work is limited to the following questions on the existing knowledge on the structure and petrology of the Kudaru complex:

Geological map of kudaru

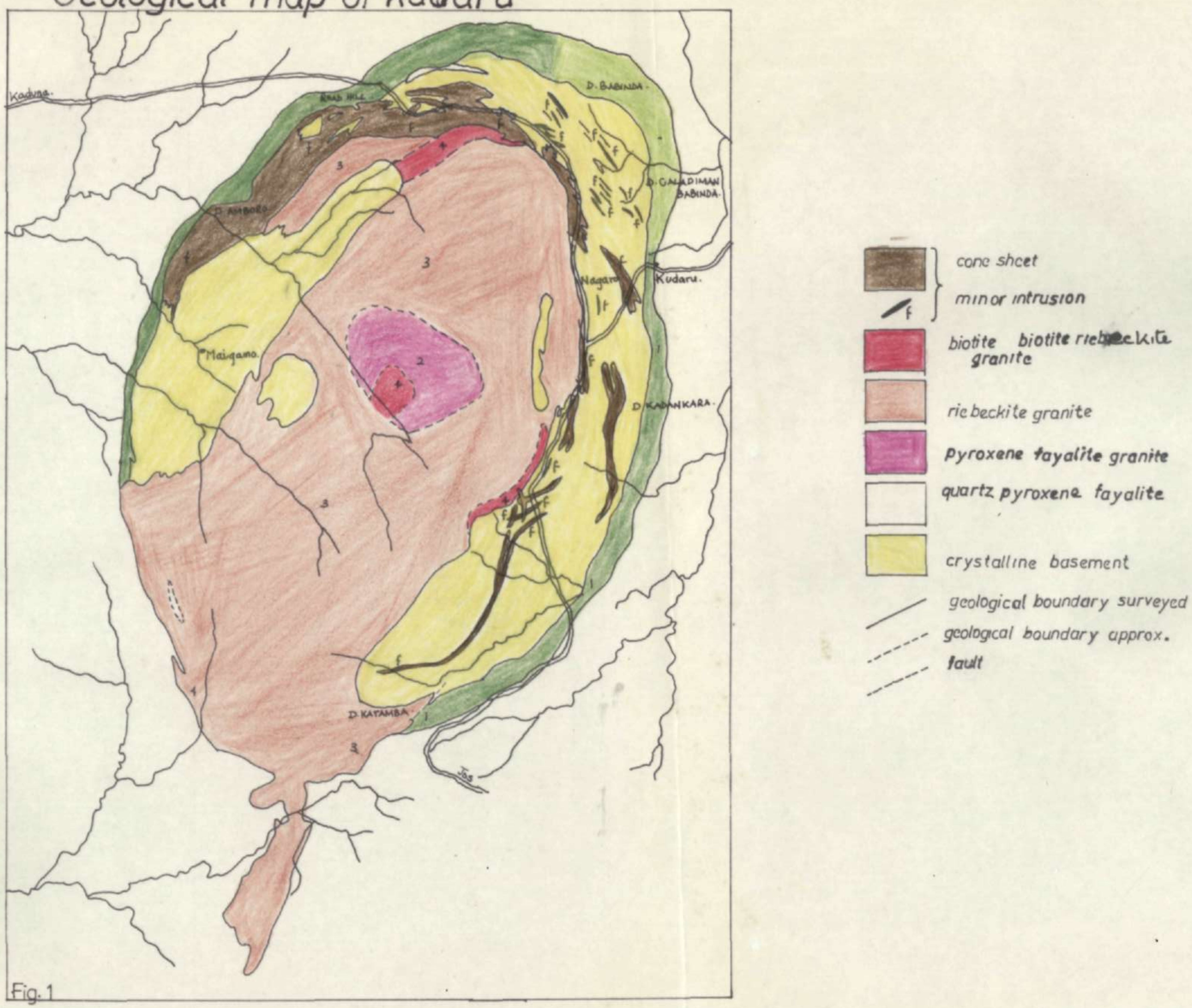


Fig. 1

a) The initial lithology of the peripheral ring-dyke: Does this ring-dyke actually consist of one initial rock-type as published in the literature?

b) Into how many rock types could the 'cone-sheets' be classified in modern terms?

c) Is there a probability that extrusive volcanic rocks may have been present within the ring-complex although they are now completely obliterated by erosion?

d) What is the structural and petrological significance of the intrusion of the main central granite beyond the confines of the peripheral ring-dyke framework?

1.3 PREVIOUS WORK

This complex was first studied by Bain (1934) during the initial survey of the Nigerian Tin fields. A brief reconnaisance survey was made by Black (1954) to investigate the possibility of the occurence of pyrochlore in the riebeckite granite. Since these earlier workers no published work has subsequently been done on this complex.

1.4 LOCATION AND ACCESS

LOCATION The Kudaru complex is in the Ikara local government area of Kadura state and is situated along the Zaria - Jos road. (fig. 1b). It's location within the Nigerian younger granite province is West-central (fig. 1c) the Kodaru village after which the complex was named has a new site that now lies within the ring complex along the

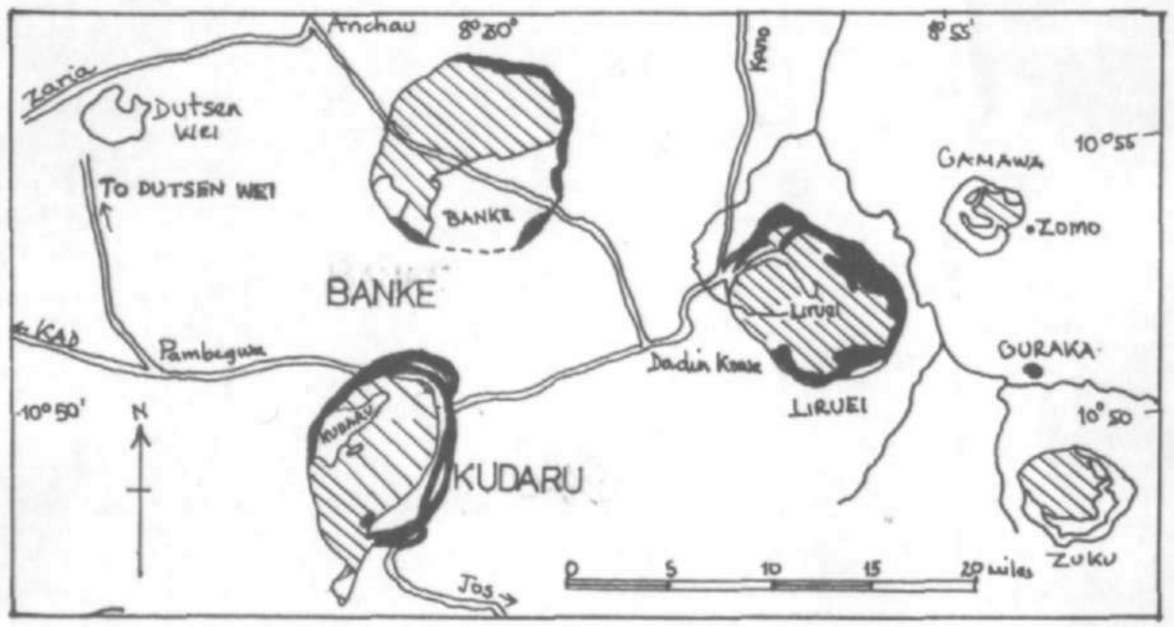
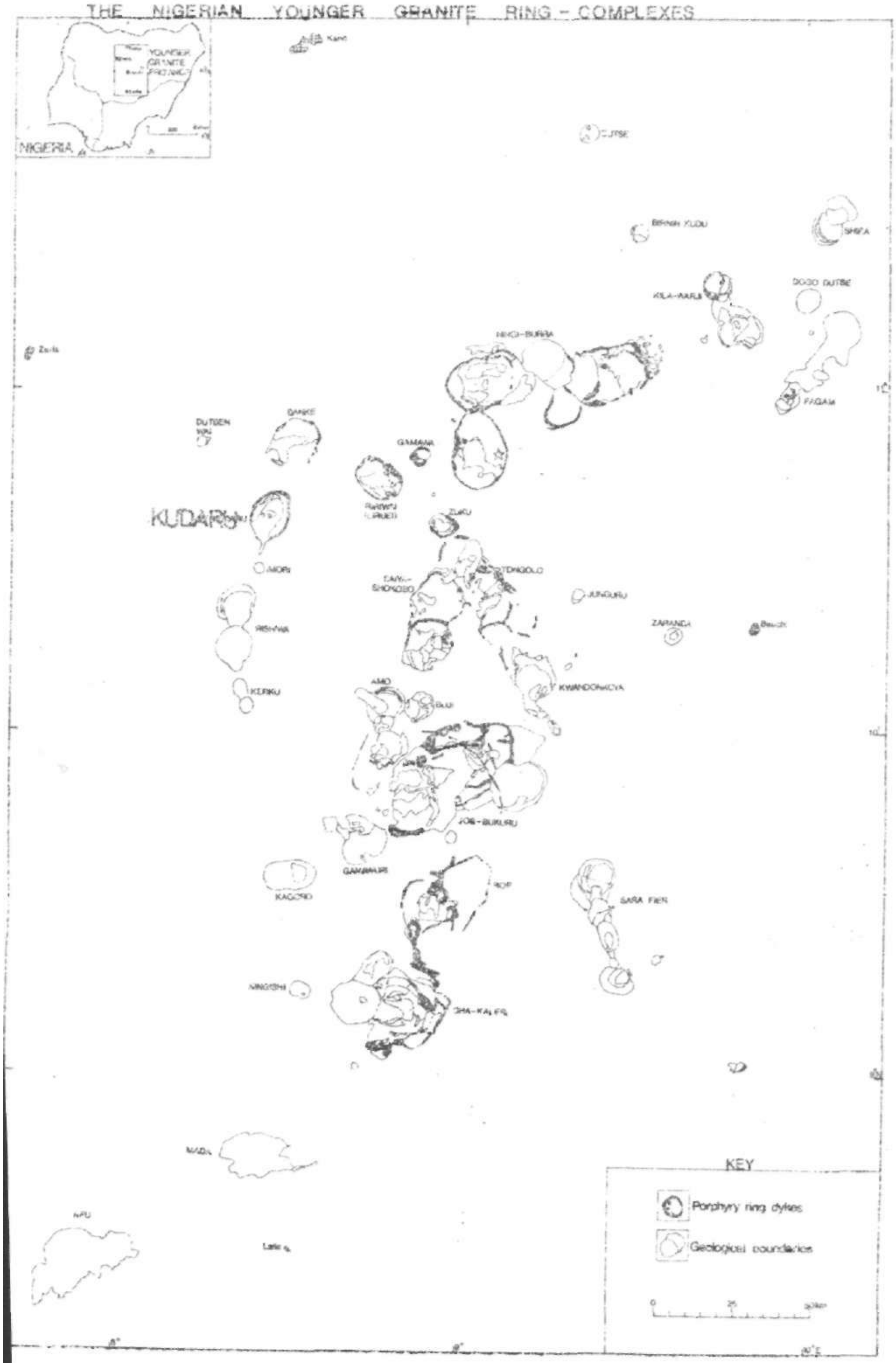


FIG.1b Location Map.

Adambako.

THE NIGERIAN YOUNGER GRANITE RING - COMPLEXES



road to Jos while the old village may be found outside the ring (fig. 1a).

ACCESS The Kudaru complex is fairly accessible being traversed by the Zaria-Jos tarred road. The complex is also traversed by numerous foot paths some of which lead to passes through hilly areas. Access is greater nearer the peripheral ring-dyke and becomes more difficult toward the central part of the complex where the topography is more rugged.

1.5 TOPOGRAPHY & DRAINAGE

TOPOGRAPHY The Kudaru complex as a whole form a very prominent topographical unit relative to the surrounding basement countryside. The highest point on the complex is the Dutsen Kudaru which stands at about 1,350m above sea level.

The complex is bounded by a very high peripheral ring-dyke which has retained its height as a result of its resistance to weathering relative to the enveloping basement rocks. This dyke attains its highest points and thickness in the north-eastern corner of the complex, at Dutsen Babinda and at Dutsen Galadimon Babinda.

Where the central granite pluton does not come into contact with the peripheral ring-dyke, the topography of the intervening basement area between them is generally low. But it has been observed that this lowland within the ring-dyke is generally higher than the basement lowland outside the ring-dyke.

The central pluton is extremely rugged and truncated. At the fringe of this pluton, are the cone-sheets which have a fairly lower elevation than the pluton itself.

DRAINAGE

The drainage on this complex is determined by the major j joint, pattern developed on the bare massive ridges of the central granite intrusion.The drainage is radial. The central area serves a source from which many streams take their rise and flow outwards from the complex. Most of the streams found here are seasonal and flow only in the rainy season.

CHAPTER TWO

A SUMMARY OF THE STRUCTURE AND PETROLOGY OF THE NIGERIAN YOUNGER GRANITE COMPLEXES

2.1 INTRODUCTION

The Nigerian Younger Granite province contains over forty separate anorogenic ring-complexes. These complexes vary in size from less than 2 km^2 up to 1500 Km^2. The province defines a north-south zone, approximately 300 Km wide, in the north central part of Nigeria. However, it has been established (Black, 1963) that the Nigerian province extends to Niger Republic.

Migration of the Younger Granite ring complexes, has been observed (Bowden _et al_; 1976) and related to the general north-south trend of these complexes. According to the migration concept of Bowden and co-workers, magmatism commensed in the Air region of Niger Republic in early silurian and seemingly terminated in the sou-thern end of Nigeria province in late Jurassic period. It is believed that the Nigerian group ranges from Upper Triassic to Lower Jurassic.

From results obtained from the mapping of the various ring complexes of the province, it has been found that the individual ring-complexes of the province are made up of a broadly similar type of rocks.

2.2 STRUCTURAL FEATURES

The Nigerian Younger Granite ring complexes are distributed along a north-south zone. It has been observed by earlier workers that a line of demacation can be drawn about latitude 10°N on a map of this province, thereby separating those complexes at the north from the group at the south (fig.

A very important observation about this hypothetical line is that to the north of this line, the complexes found are structurally simple, showing very many isolated rings and this can be shown to have been formed as a result of a simple cycle of magmatic activity. Very important also is the degree to which most of the extru-sive rocks in the north have been preserved. Infact, in some complexes, they have accounted for a substantial proportion of the total surface area, eg. Banke, [illegible] and Ningi-Burra complexes. The most important structural features of this region is the ring-dyke which in most of the cases occupy peripheral positions in the complexes. These dykes therefore delimit both the shape and outer extent of the individual complexes, cone-sheet are also another structural feature that is almost exclusively restricted to this northern sector.

On the other hand, the southern complexes are characterized by the development of multiple intrusion of plutonic rocks, always occuring in a [illegible]erposed form. Unlike in the north, porphyry ring dykes are rare and where they occur, they are not very regular in shape. They are very big and complicated inform e.g. sara Fier complex (Turrer 1962) (fig. 10). In this complex, the plutonic plo rocks which are defined as ring structures are well preserved because of migration of subsequent intrusive centres. Each of the centres is of course the centre of multiple rings.

The structural differences between the northern and southern sectors of the Nigerian Younger Granite province according to some workers may be a matter of differential erosion. The degree of erosion in the south tends to be greater than that of the north and so most of the structures which can now be readily seen in the northern zone have already been eroded in the south and so cannot be seen. The restricted occurence of griesen vieus which are structures associated with roof zone phenomena to the north has also strenghtened this supposition.

The major structural features in the younger granite province include:

1. Ring-dykes
2. Cone-sheets and Radial dyke swarms
3. Central intrusions.

2.3 RING DYKES

The ring-dykes constitute one of the most important structural features in the younger granite complexes. The ring-dykes have various shapes which include circular, elliptical and polygonal types. Usually they have diameters ranging from 2 - 25 Km. Very often, the rings are incomplete, showing some form of discontinuity particularly at the surface level. The ring-dykes normally have an attitude which are in most cases close to vertical. The ring-dykes mostly enclose all other rock units and sometimes even the basement. They are made up of two porphyry rock types namely:

- Granite porphyry
- Quartz porphyry

2.4 CONE-SHEETS AND RADIAL DYKE SWARMS

The term "cone-sheets" is a structural term which refers to certain minor intrusions that are characteristically very thin, tangential in distribution and dip inward. Individual bodies are often only a few meters thick and have angle of dip between 30^{o} and 60^{o} towards the centre of the complex. The cone-sheets, when observed individually, are irregular and discontinous but occur usually in swarms. These form broad bands within the ring-dyke frame-work but may be occasionally found outside the ring-dyke (Fig. 2b) Radial dykes swarm are very few but are still found around the complexes. Very often large radial dykes break across the ring dykes to intrude the outer basement (Fig. 2c).

2.5 'CENTRAL' INTRUSION

It has been observed Turner (1972), that the central part of each of the complexes in the Younger Granite province is occupied by granite intrusion. They form outcrops pattern which look circular concentric or irregular. They generally dip outward

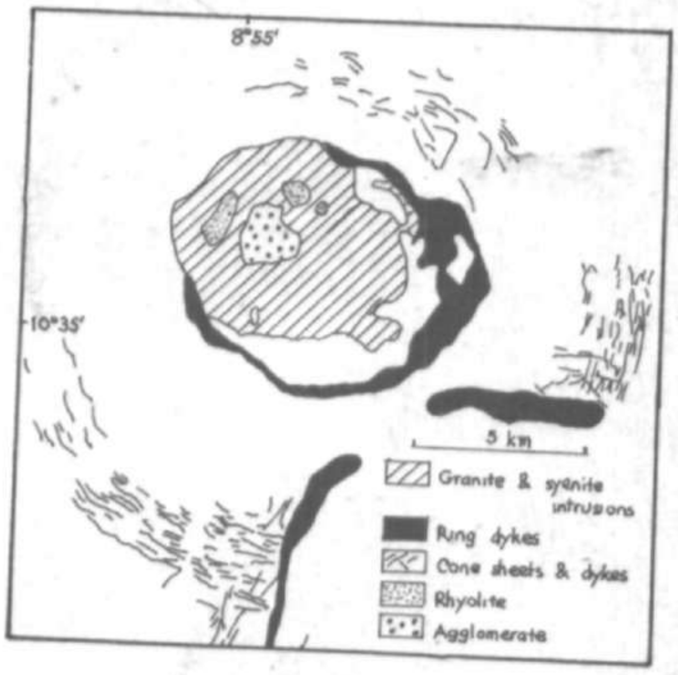


Fig 2b. Cone sheets around the Zuku complex. (After Turner. (1972))

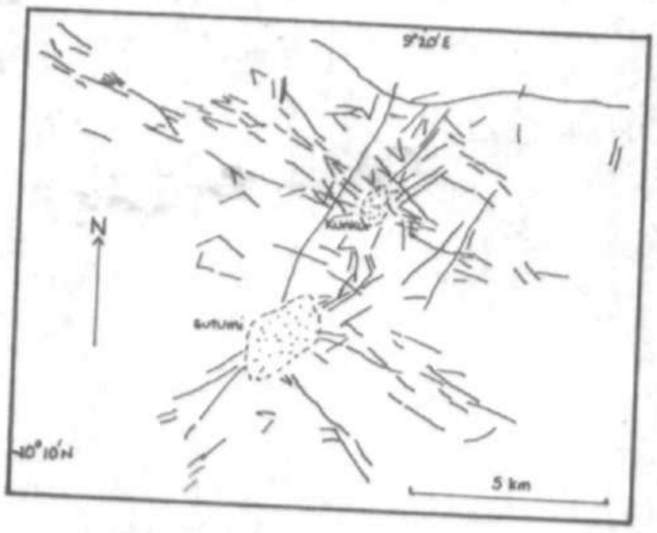


Fig 2B. Radial dykes associated with the Kunkur and Sutumi intrusions (After Turner (1972)) to the outer ring. This has been caused by the upward movement of magma at the time of underground cauldron subsidence. Most of these intrusions are usually very massive e.g. Riebeckite granite in Kudaru complex.

Two mechanisms have been advanced for their emplacement. These are:

(a) Underground cauldron subsidence

(b) Piecemeal stopping.

2.6 PETROLOGY

Rocks found in the Nigerian Younger Granite province include volcanic rocks, subvolcanic rocks and plutonic rocks (Table 1)

I VOLCANIC ROCKS	PYROCLASTIC ROCKS e.g. Breccias, Agglomerates, Tuffs LAVAS. Rhyolites, Basalts Tracytes
II SUBVOLCANIC ROCKS	Granite porphyry and Quarts porphyry.
III PLUTONIC ROCKS	Biolite Granite, Riebeckite Granite, fayalite bearing granite syenite, and Gabbros

VOLCANIC ROCKS

The volcanic rocks fall into 2 separate groups in this province. These are the pyroclastic rocks and the lavas. This distinction is based principally on their mode of formation while the pyroclastic are composed of those rocks formed as a result of voilent explosion or eruption of magma Rhyolites are those formed from flows.

The pyroclastic rocks are always fragmental in character and have breccia, agglomerate and tuff as examples. Rhyolites can be divided into 2 groups. These are the earlier rhyolites and the late rhyolites (Turner 1976). The early rhyolites are products of vent eruption and generally they show very big disparity in their composition and texture. Texturally rhyolites ranging from porphyritic, spherulitic and glassy varieties have been identified.

The rhyolites are chemically identical to granite. They also have the same range of alkalinity. Rhyolites have various colour and texture. Their colour ranges from grey and brown to green in alkaline varieties. The early rhyolites have phenocryst which vary greatly in size and number and so it is not very easy to identify it as porphyritic. The late rhyolite is however typically a porphyritic rock with a very high percentage of phenocryst content, up to 50% or more.

SUBVOLCANIC ROCKS

The rock types found in this group are the granite porphyry and the quartz porphyry. The two porphyries form the majority of the ring dykes in the province.

The granite porphyry normally has greenish grey colouration when unaltered. The feldspar have euhedral shapes. It normally has a groundmass which is granitic in texture. The mineral present in this rock are quartz, alkali feldspar, amphiboles pyroxene and mica. It is believed that this rock has greater range of chemical composition than other granite like biotite and riebeckite granite (Turner 1972).

The quartz porphyry is similar in many respect to granite porphyry. It is a porphyritic extrusive or hyperbasal rock containing phenocryst of quartz and alkali feldspar (usually orthoclase) in a microcrystalline or cryptocrystalline groundmass (Turner 1972). It is occasionally refered to as porphyritic rhyolites.

The phenocrysts (Feldspar and Quartz) are usually not as big as the granite - porphyry but always having a fragmental shape. The rock therefore has ignimbritic texture with all the major crystals broken in Fragments.

The mafic minerals of this rock if unaltered are fayalite, ca-rich pyroxene, amphibole are present in hydrothermally altered porphyry.

Chemically, the two rock types are similar and the major difference seem to be in the texture for while the granitic porphyry has a coarse and euhedral crystal in the granite groundmass, the quartz porphyry has an igmimbritic texture in a fairly fine grained groundmass.

THE PLUTONIC ROCKS

BIOTITE GRANITE

This is the most abundant and widespread among the rocks of Younger Granite province. They are found in almost all the individual complexes. They form some of the largest intrusion in the province.

Petrographically, they contain 25-35% of free quartz and there are both potash feldspar and plagioclase feldspar in them with plagioclase content showing some compositional range between Ab_{85} - An_{15} and Ab_{95} - An_5. Deuteric albitization at later stage is a common process. Three forms of biotite granite are found in this province (Turner 1972):

a) Coarse grained biotite granite. This is Pinkish in colour has widely spaced joints within them.

b) N'gell types is medium grained and has both pinkish and white coloured types.

c) Rayfield gona type is fine grained and has biotite growing in separate flakes rather than in clusters.

Generally, tin mineralization in the younger granite province is al-most entirely associated with biotite granite.

RIEBECKITE GRANITE

The riebeckite granite in the Nigerian Younger Granite province occupies an extensive area believed to be the largest area covered by riebeckite granite in the whole world (Macleod et al; 1948).

Like the biotite granite, they appear in many of the complexes of the province and wherever they occur, there is usually no difference in their mineralogy and texture. The texture of the rock grades inwards i.e. very fine grained at the margin (contact) and coarse grained at the middle of the rock.

Petrographically, riebeckite granite is peralkaline according to shand's classification. Many of the riebeckite granites contain aegirine which is intergrown with soda amphibole. Biotite is absent, except for a little occurence in the pegmatites. This rock has the same porportion of free quartz as the biotite granite and the aggregation is higher in biotite granite than in riebeckite granite. Microcline - microperthite is the common feldspar. Astrophyllite and pyrochlore are also found in this rock. (This is a very unusual association (M.S. Buchanan et al; 1971). Accessory mineral in the rock include cyolite, thomsenolite, flourite, thorite, and ilmenite. There is no columbite yet recorded in this rock.

FAYALITE BEARING GRANITE

The occurence of this rock in the province is very localised. The rock was first recorded at Kudaru by Bain (1934).

The rock is coarse grained and the porportion of the free quartz is slightly lower than those of Biotite and riebeckite granites.

Petrographically, the rock contains quartz, alkali feldspars, fayalite and amphibole. The most surprising mineral association in this rock is the coexistence of fayalite with other mineral? It's occurence can be explained by saying that the melt which formed this rock was a dry one?

BASIC ROCKS

The occurence of basic rock has not yet been well recorded and where they occur they form minor intrusion in and around the complexes. These intrusions include dolerite dykes, some gabbroic intrusions, etc. These rocks are rich in ferromagnesian minerals e.g. Feo, Cao, Mgo.

PETTERN OF IGNEOUS ACTIVITY

Two major cycle have been advanced and these are:

(a) Volcanic cycle

(b) Intrusive cycle.

The volcanic cycle has been subdivided into three stages on the basis of lithology. These are as follows.

i) The Pre-caldera eruption

ii) Caldera forming stage

iii) Post caldera eruption.

(i) Pre-calderal eruption

This was probably the first of the series of eruptions in this province and it is this eruption that formed the volcanic cones which subseqently became the centre of caldera collapse. This eruption were probably located within the areas of present cauldrons. It is suggested by some worker that the main structures formed at this stage were shield volcanoes.

(II) Caldera Forming Stage

The rapid emission of magma in ash flow that occured in the first stage brought about caldera collapse. Caldera formation was accompanied by the accumulation of thick intra-caldera crystal-rich ignimbrites and the emplacement of a ring dyke of granite porphyry. Their repeated association has helped to show their importance in the development of the Nigerian ring complexes.

iii) Post Calderal Eruption

Very little of this eruption is known in the Nigerian ring complexes as there is no direct evidence of renewed volcanism, in the calderal. Some volcanic rocks might however have been extruded. Lack of evidence for post-caldera eruption may be due to non-eruption because it is believed that magma which should have been used in the renewed volcanism usually migrated to another site to form an entirely new ring complex.

THE INTRUSIVE CYCLE

The intrusive cycle is basically a simple cycle in which the intrusive rocks have crystallized in a subvolcanic magma chamber. This cycle is the last cycle that occured in most of the ring complexes. It came later than the ring complexes and this can be seen in places where the central intrusive rock cut across the

PROBLEMS OF PETROGENESIS

The origin and evolution of magmas that formed the Nigerian Younger Granites remain in controversial topic (Ike, 1979). Many workers have expressed various views which include the following:-

a) Parental syenitic fluid got directly from the upper mantle; with peralkaline silicic variants formed by 'crustal enrichment' of syenitic liquid and perallunimous biotite granite obtained either as further modification of the syenitic fluid or at independent derivation of the dioritic lower crust. (Van Breemen et al., 1975)

b) Parental hornblende fayalite granite fluid derived directly from the upper mantle through partial melting and associated with divergent peralkaline and peralluminous trend through fractional crystallization, depending on the operating physical parameter (Macleod et al., 1971; Jacobson and Macleod 1977).

c) Parental syenitic and acid magmas from partial melting of crustal and subcrustal rocks (Black and Girod, 1970).

d) Mantle-derived basaltic fluid which underwent crystal fractionation simultaneously causing crustal anatexis from which a second parental acid magma was formed (Turner and Bowden, 1979).

Many workers are of the opinion that the fourth idea is the likely source of the magma e.g. in the Tibchi complex, there is significant evidence for a parental basaltic liquid, presumably from the upper mantle, that evolved through fractional crystallization (Ike, 1979). There is increasing evidence that crystal fractionation played a major role in the differentiation of basaltic parent magma. However, the large volume of granitic rocks in the province as compared to the apparantly limited proportion of the original basalt and gabbro occurence, suggests that extensive crustal melting might have taken place as well. In that case, the basaltic magma would have provided the heat necessary for the resulting process.

CHAPTER THREE

KUDARU COMPLEX

3.1 GENERAL GEOLOGY

3.1.1 SHAPE: The Kudaru complex is defined by an elliptical peripheral ring-dyke. The major-minor axes of this elliptical frame work are

respectively. The ring dyke is truncated in the south by the c central granite intrusion which extends southwards. Altogether the complex occupies a surface area of about 30 kilo. by 15 kilo. The ring dyke is enveloped by the basement rock on its outside. To the inside of the ring however the basement rocks are also found enclosed by the dyke.

3.1.2 MAJOR STRUCTURAL FEATURES

THE RING DYKES: The ring dyke encircles all other structural and lithol·gical units of the complex and stands high and couspicuous relative to the . basement rocks. As a topographical feature, however the continuity of the ring-dyke is breached at irregular intervals by streams running outwards from the centre of the complex. The maximum width of the dyke is about 400m while the minimum width may be less than 150m. The ring dyke is made up of 2 rock types, Quartz porphyry in the north and granite porphyry in the south (Fig. 3.1.2a)In the granite porphyry sector, xenoliths of quartz porphyry ranging from 50m to microscopic dimensions have been observed. Throughout the ring dyke as a whole there are occurences of dark fine grained xenoliths probably belonging to earlier volcanic rocks.

CONE-SHEETS: The cone-sheets in this complex are found mostly at the fringe of the central granite pluton but located within the enclosed basement rocks. Generally the cone-sheets have a lower elevation relative to the central pluton and occur as a swarm. Strictly, however, the age relationships suggest the presence of more than one set of swarm. For example, the central pluton has in some localities e.g. opposite New Kudaru village, been transgressive on some cone-sheets, though the converse appears to be the case for others. In dimension the cone-sheets are on the average less than 500m wide although lengthwise they may be up to 4Km. The cone-sheets consist of variable lithology being made up of microgranite, granite porphyry and intrusive rhyolites.

CENTRAL GRANITE PLUTON

The central granite pluton is the largest lithological unit within the complex and occupies a surface area of about $45Km^2$. The pluton is centrally located within the complex along the east-west axes, but displaced southwards along the north-south axes, to the extent that in the south it truncates the peripheral ring-dyke. It is a rugged mass of riebeckite granite whose contact with neighbouring rocks are always sharp. In the centre of the pluton, is a small body of fayalite bearing granite. Texturally, there is a gradation from its fringe to its centre. At the fringe where it has contact with cone-sheets and the enclosed basement rock, the riebeckite granite pluton appears fine grained, with characteristic miarolitic cavities. These miarolitic cavities are considered as evidence of the roof zone or contact facies of the pluton. As one moves towards the centre, the rock increases grain-size reaching maximum coarseness in the central areas. Because of this coarseness at the central area, the rock here has become very susceptible to weathering and this has produced the rugged topography that is observed. Unlike most main granite plutons found in other complexes, such as in the neighbouring Liurei and Banke complexes the central granite pluton in the Kudaru complex is observed to be very poor in mineralization.

3.1.3 TECTONICS SEQUENCE

The Kudaru complex appears to have witnessed a series of magmatic activities which according to Bain (1934) may be summarized in a sequence of six episodes or intrusions in the following chronological order:-

6. Coarse quartz-porphyry dykes with riebeckite biolite and aegirine.
5. Fine grained Quartz-porphyry, rhyolites and microgranites cone-sheets.
4. Riebeckite and Biolite granite.
3. Quartz-porphyry and rhyolites, cone-sheets.
2. Pyroxene-Fayalite granite
1. Quartz pyroxene-fayalite-porphyry ring intrusion.

But from the present study the following geological sequence is favourd

5. Cone-sheets and minor intrusion.

4. Biotite and Biotite reibeckite granite.

3. Pyroxene Fayalite granite

2. Ferrohedenbergite Granite porphyry ring intrusion and cone-sheets.

1. Fayalite Ferrohedenbergite Quartz porphyry ring intrusion.

3.1.4 PETROGRAPHY

FAYALITE FERROHEDENBERGITE QUARTZ

PORPHYRY AB 7

MEGASCOPIC DESCRIPTION: This is a dark grey rock which is holocrystalline with medium grained cystals. The crystals have diameter ranging from 2-3mm. Feldspars and Quartz appear as fragment phenocryst in the fine grained groundmass. There is a very high percentage of mafic mineral. They carry about 40-45% of the groundmass. The fineness of the groundmass coupled with the colour of the pyroxene (mafic mineral) has given the dark grey colour of the rock. Because of the fragmental nature of the phenocryst, the rock has an ignimbretic texture.

MICROSCOPIC DESCRIPTION

In thin section, the rock has a generally fine grained groundmass in which pyroxene is the predominant mafic minerals. There are spherulites in the rock. Fragmental Quartz and feldspar are the phenocryst in the rock. Other minerals found in the rock are amphibole, olivine and iron oxides. Apart from the feldspar and Quartz phenocryst, the minerals of the groundmass are of the range of 1-2mm.

Pyroxene is the most abundant mafic mineral in this rock and appear as phenocryst. This pyroxene is observed under the microscope to be length fast and has not be altered. They are found in association with some apague minerals and fayalites. The pyroxene is mostly olive-green in colour. Some of them are rimmed by amphiboles.

The feldspar phenocryst here are fragmental, and are turbid in colour with fracture criss-crossing them.

Olivine with its characteristic prismatic and bipyranidal ends and concordal fractures are observed. They are yellowish brown in thin section and changes to yellow under cross polars. They are found in association with some opague minerals – (haematite). From the colour of the mineral, it is iron rich olivine (fayalite). Along the fractures of the mineral, some alteration products can be observed. These are serpentine.

Amphiboles, probably hornblende occurs as pale green to deep blue specks in the groundmass. The mineral is on the average less than 1mm in the groundmass. Iron oxide occurs as accessory mineral.

FERROHEDENBERGITE GRANITE PORPHYRY AB 1

This rock has a light bluish colour with occasional occurences of greenish specks. It is holocrystalline with an average grain diameter of about 5mm, therefore making it coarse grained rock. There are also some phenocryst of feldspar and Quartz in the coarse grained groundmass. Minerals identified megascopically include feldspar and Quartz.

MICROSCOPIC DESCRIPTION

In thin section, the rock is holocrystalline with individual crystals having an average size of about 3.5mm-5mm. Feldspars and quartz standout as phenocryst in the groundmass, many of the crystal of this rock have euhedral shape with only very small proportion of fragmented crystals. Very important about this rock is the preponderance of spherulitic structures which is forming much of the groundmass. The mafic component of this rock appear in clusters and they are always found in association with some opague minerals. Minerals found in this rock include pyroxene feldspar, amphiboles and Quartz.

The feldspar in this rock are turbid and brownish in colour. The crystal are mainly in the range of 4.5mm long and are mainly euhidral in shape. This give the porphyritic texture of the rock. What might be regarded as zonning is clearly seen in many of the grains. They are also fractured (fig. 3.4.1). Twins are rarely seen but when they are found they are more of calsbad twins.

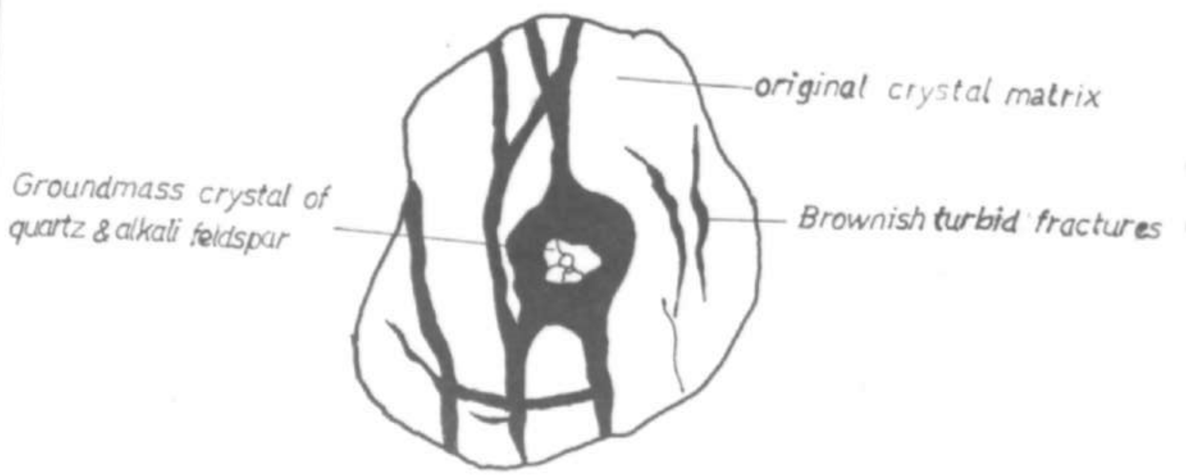


fig.3.3a ZONING & FRACTURING IN FELDSPAR

Myrmekitec structures are also found in the rock. (Plate 3.4.1a)

Pyroxene occurs in a very high proportion as against amphiboles. The crystals are olive green in colour and occur as little fragments with an average size of about 1-2mm long. Amphibole are found rimming the pyroxene (Plate 3.4.1b) Euhidral crystals of this mineral are rarely seen. The mineral is moderately pleochroic.

Comparatively, amphibole is very minute in proportion relative to pyroxene. They are deep blue in colour and often fragmented. They occur as minor fringe to the pyroxene or scattered reliculate crystals in the groundmass. Occasionally some amphibole crystals are observed to have been altered in more than one place.

Quartz appear in the groundmass as fragments and shows many wavy extinction. Accessory minerals observed include haematite and magnetite.

Plate 3.4.1a Myrmekite in granite porphyry ..X 40

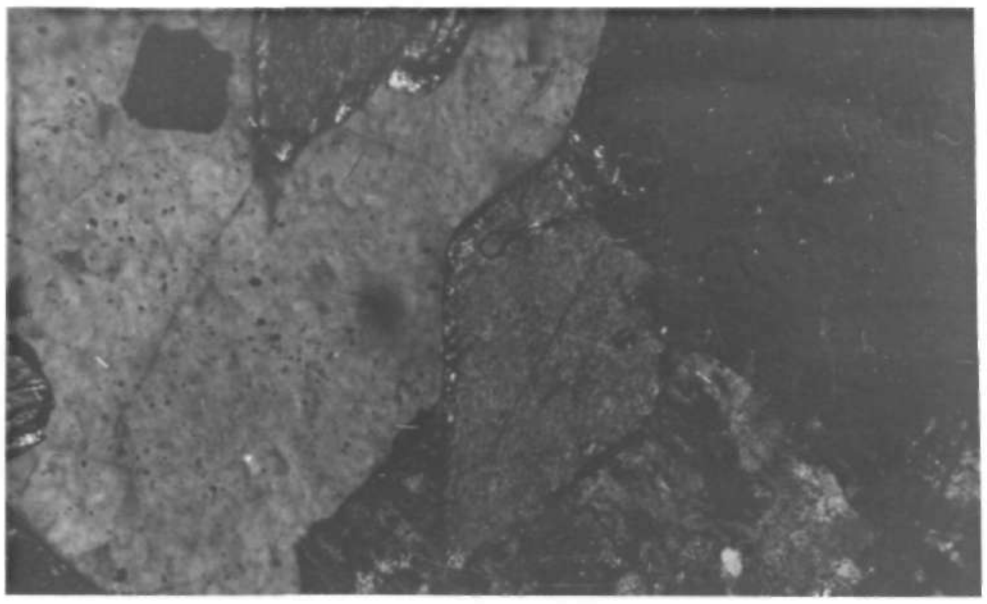


Plate 3.4.1b Amphibole rimming pyroxene .X40.

FAYALITE GRANITE AB 17

MEGASCOPIC DESCRIPTION

The rock has a yellowish green colour and is equidimensional in texture. It is also holocrystalline. The crystals range in size from 3-4m in diameter. Feldspar crystals appear to be in abundance. There is a sporadic occurence of mafic minerals. In handspecimen the feldspar looks yellowish and turbid. Minerals identified magascopically include feldspar, quartz and a cluster of ferromagnesian minerals.

MICROSCOPIC DESCRIPTION

In thin section the minerals are equidimensional with grains ranging from 2-3mm and mostly subhedral. The essential minerals include feldspar, pyroxene, olivine, amphibole and quartz.

Feldspar is the dominant mineral. It carries about 55-60% of the rock. They are very turbid obscuring the real colour. They are coarse grained with crystal diameter of about 4-5mm. Feldspars of this rock are mainly alkali feldspars with minor plagioclore . The latter in the range of albite-oligoclose the alkali feldspar is mostly perthite Blate 3.4.1c)

There is a small proportion of pyroxene in the rock. There is virtually no difference between the pyroxene of this rock and that of AB 1 and 7 which have been optically identified as ferrohedenbergite.

Olivine occur as fayalite in this rock and in clusters thereby giving a feathery structure which is radiating or reticulate in appearance. They are yellow to red in colour Plate 3.4.1d.

The accessory mineral of this rock is Iron oxide which is brownish in their section.

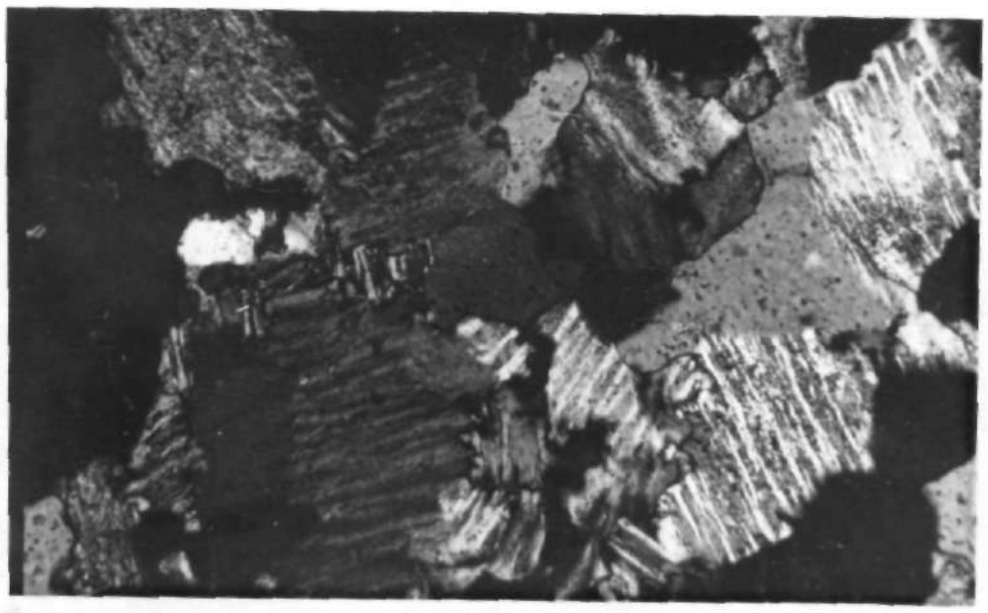


Plate 3.4.1c Perthite in Fayalite granite ..X40

Plate 3.4.1d Fayalite in Fayalite granite .. X40

AMPHIBOLE GRANITE

MICROSCOPIC DESCRIPTION

This rock has a pink colour and is coarse grained with an average grain size of about 5mm. Occasional occurence of big feldspars are recorded. Mafic minerals of this rock occur in patches all over the rock. Occasionally, some needle like mafic minerals are found occuring in rock. Minerals that can be determined megascopically include quartz and feldspar.

MICROSCOPIC DESCRIPTION

The rock is holocrystalline with individual grains ranging in size between 4mm-5m in diameter. There are patches of mafic minerals occuring sporadically. The following minerals have been identified, quartz, feldspar, amphibole and accessory mineral.

Both plagioclare and Kfeldspars occur in this rock. The occurence of plagioclare in the rock is very limited and it is in the range of albite-oligoclare. Also some potassium feldspar with cross hatch twinning has been observed. The feldspars are in most cases altered and fractured. Sericite is found replacing some of the plagioclore feldspars.

Very deep-blue to indigo blue amphiboles which appear to be radiating and rather shapeless aggregate have been observed. They are also needle like. There is very little alteration but where they are altered, the altered ones look brownish in colour.

Quartz is very dominant in the groundmass and accessory mineral of this rock is Iron oxide.

FLOW RHYOLITE AB X 10

MEGASCOPIC DESCRIPTION

This rock has an ash grey colour with bandings appearing on the rock. It is very fine grained alsmost beconing glassy in texture. In the banding, dark and light band alterate. Because of the finess of the grain size, no mineral can be identified megascopically. (Plate 3.4.1e).

MICROSCOPIC DESCRIPTION

The rock is made up of very fine grained mineral. The minerals appear in needle-like from and are greenish in colour. This mineral has very high refractive index. The green minerals also in some places appear as patches and showing some faint pleochroism. It is probably aegirine augite. The identification of this minerals is not possible because of their small size. The minerals tend to appear in series of bands in their section. (Plate 3.4.1f)

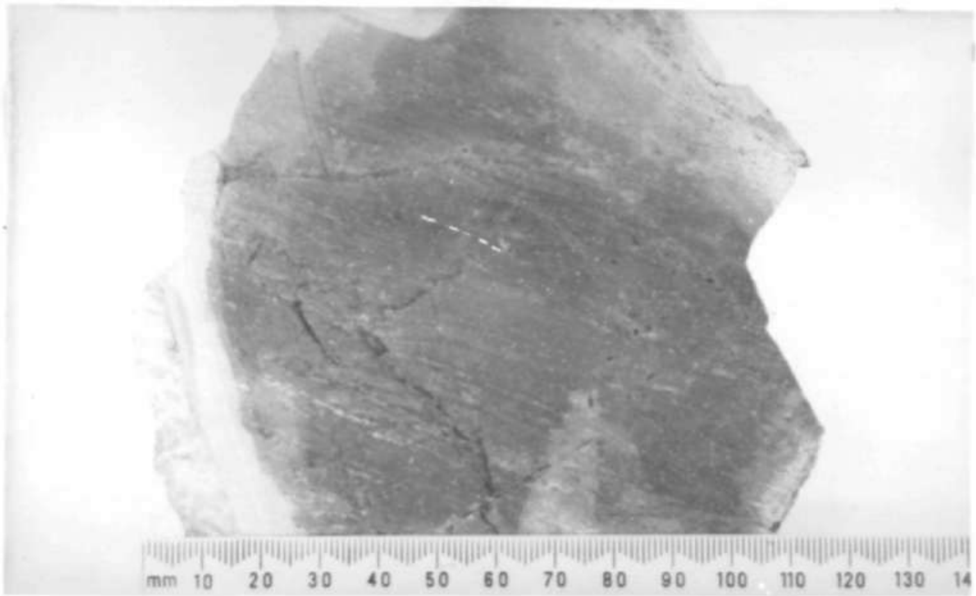


Plate 3.4.1e Banding in Rhyolite X.40.. ...

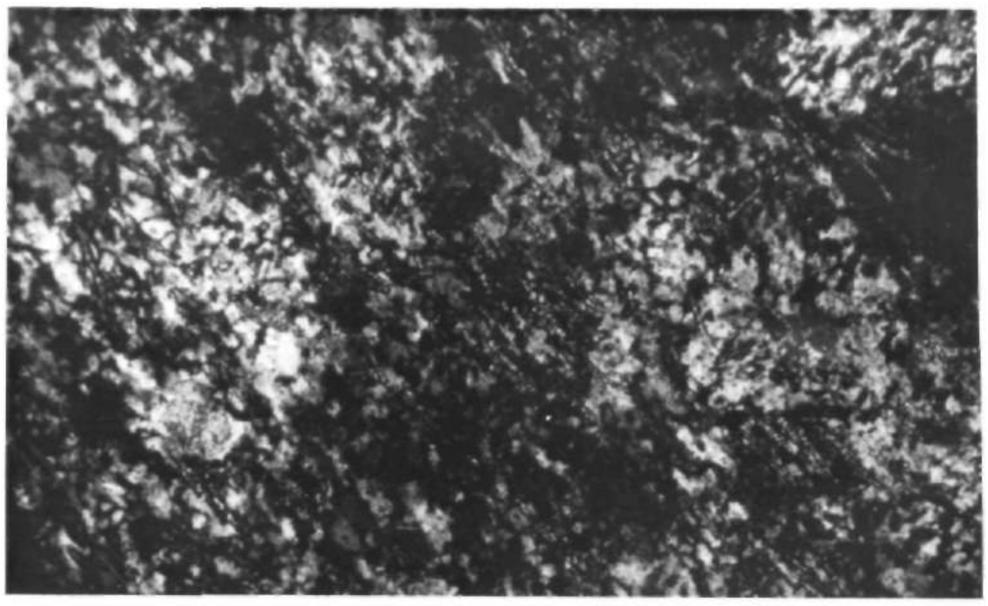


Plate 3.4.1f Rhyolite under microscope ...X.40

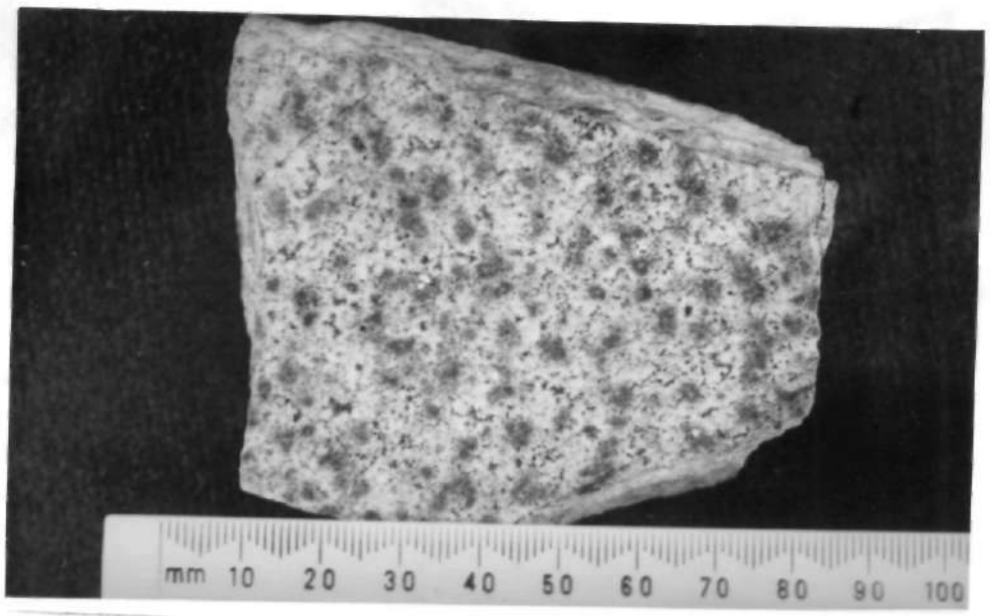


Plate 3.4.1g Spherulite in handspecimen .. X40

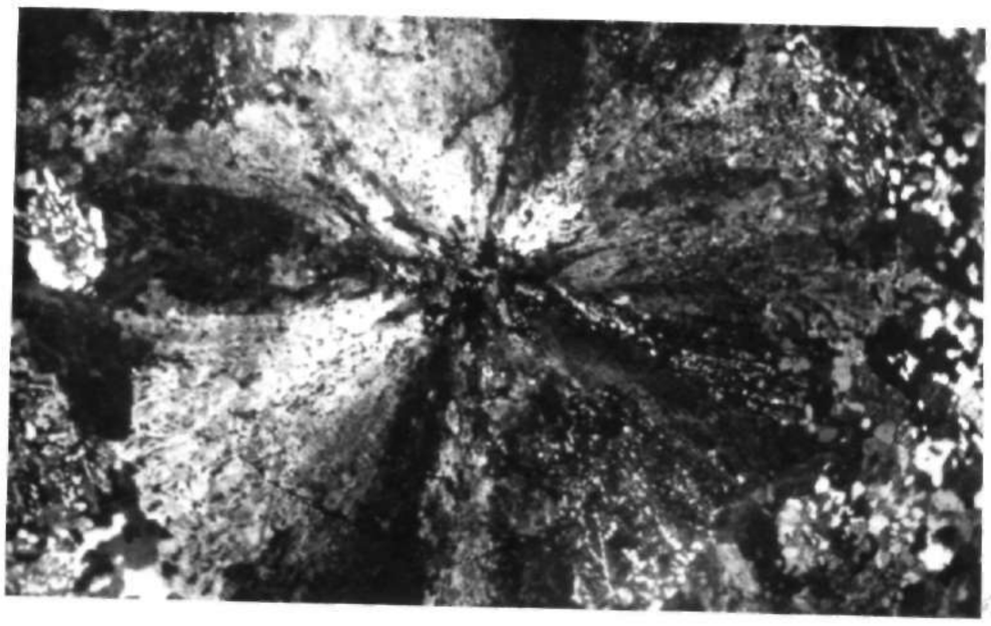


Plate 3.4.1. Spherulite under microscope X40

MISCELLANEOUS ROCKS (FORMING THE CONE-SHEETS)

AB 9. FINE GRAINED RIEBECKITE GRANITE.

This rock has a pinkish colour and has a very fine grained texture. The grain size ranges from 0-1mm in diameter. The rock has a very high percentage of quartz and feldspar and a very small amount of mafic mineral occuring as specks. Minerals that can be megascopically identified include quartz and feldspar.

MICROSCOPIC DESCRIPTION

In thin section, the development of micrographic and spherulitic structures is prominent. These micrographic inter growth tend to radiate from the centre outwards. There are patches of opaque minerals (Iron oxides) plate3.4.1 with which are associated some greenish minerals supposed to be aegirine.

Riebeckite is common in occurence although they are very small in size and always in fragments. They are also deep blue to indigo blue in colour.

AB 9b

This is a rock that is pinkish in colour and also very fine grained. More than 50% of the rock's surface area is occupied by some rounded structures which are dark in colour and believed to be coarse spherulites.

MICROSCOPIC DESCRIPTION

More than 80% of the rock in thin section is made up of spherulitics structures and micrographic intergrowths (Plate)
Aegirine augite is well crystallized and is colourless to pale

greenish in colour and shows little or no pleochroism. Riebeckite amphibole are also observed in the rock. The aegirine augite usually occur singly although clusters associated with any other minerals may be found. Crystals of this minerals are fairly large in size and reaching 3-4mm in length and diameter and appears to be of the same proportion as the riebeckite amphibole.

Riebeckite amphiboles appear needle-like in the groundmass and always associated with the myrmekitic structures in the rock. Also they are in some cases appearing as specks. Their characteristic deep blue colour is prominent and helps in distinquishing them. Accessory mineral is mainly Iron oxide. (Plate 3.4.1h)

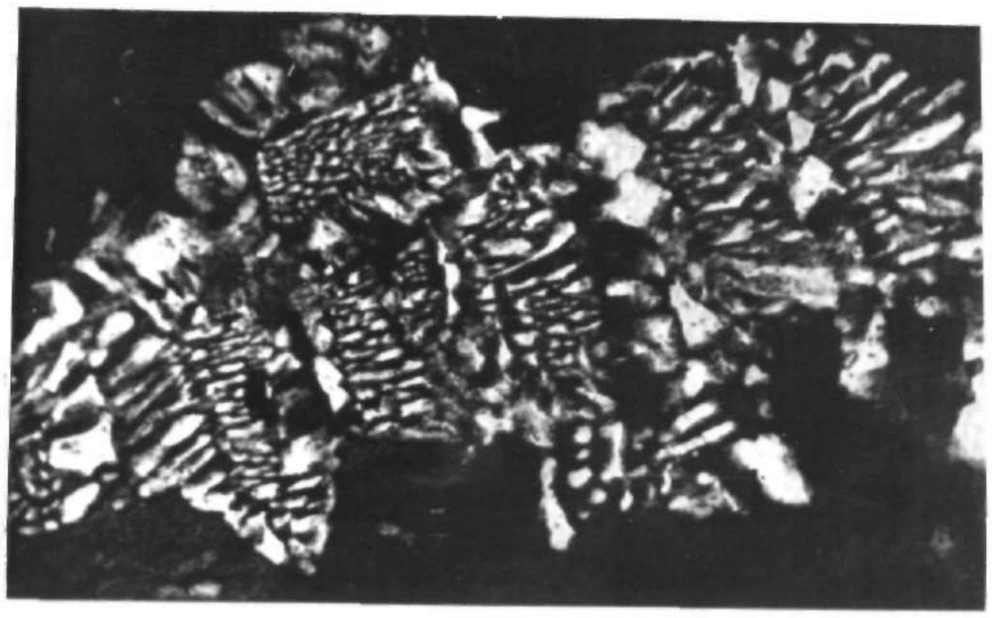


Plate 3.4.1h Myrmekite X 40

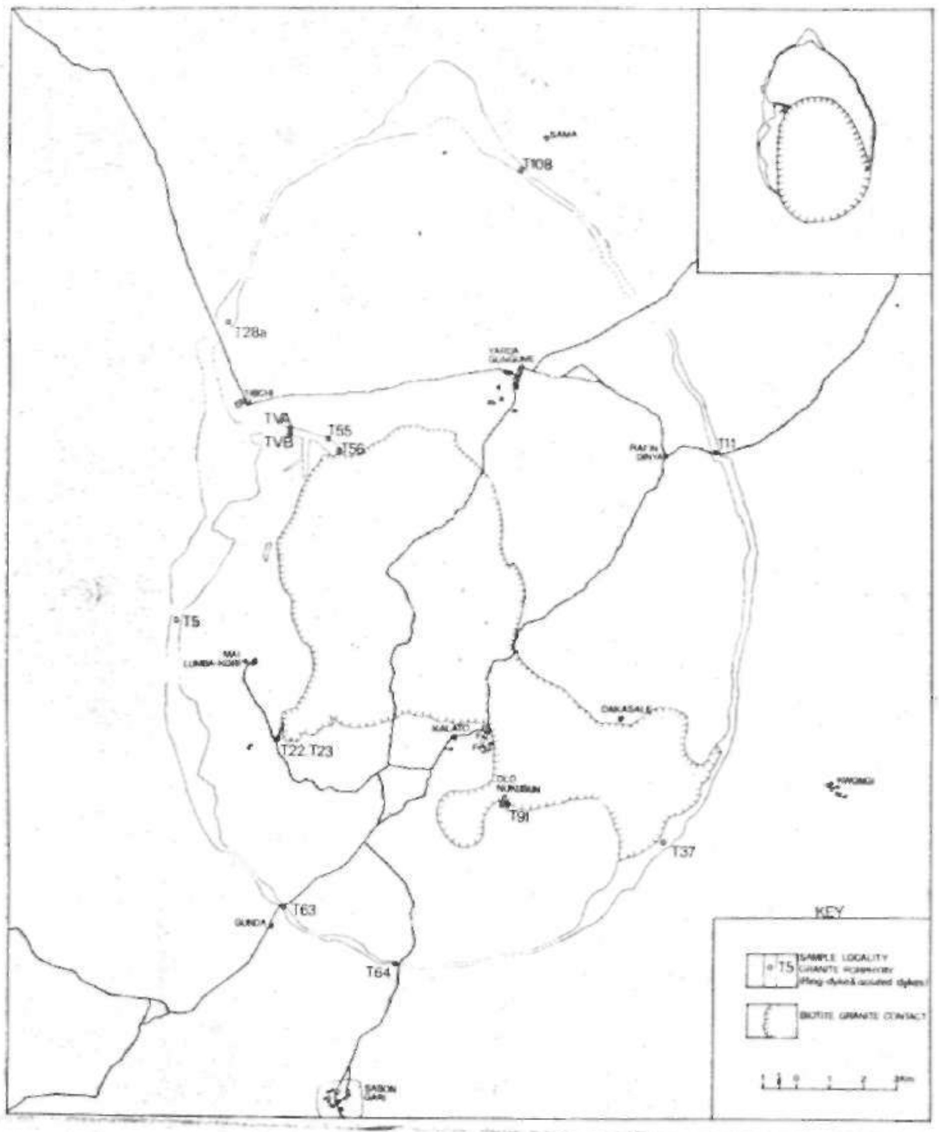
3.1.5. PETROGRAPHY OF HYDROTHERMAL ALTERATION IN THE GRANITE PORPHYRY RING-DYKE

It is possible to explain the hydrothermal alteration of the granite porphyry ring-dyke as the granite porphyry ring-dyke approaches the central pluton (riebeckite granite). The granite porphyry in the south has a contact with the riebeckite granite. After a thorough sampling throughout the periphery of the ring-dyke, it has been observed that apart from the two initial rock types of the complex (the granite porphyry and the quartz prophyry), the granite porphyry at the contact with the riebeckite granite has been hydrothermally altered. The same thing has been observed in neighbouring complexes where more detailed work has been done. For example Ike (1979) work on the Tibchi complex. The alteration of the granite porphyry decreases with distance from the contact. This alteration is however associated with petrographical changes. Fig. 3.4.1a compared with 3.4b.

TYPICAL HYDROTHERMALLY ALTERED RING-DYKE GRANITE PORPHYRY

AB 19 is a sample from the contact and gives the following information which contrast with the petrography already described of the unaltered ring-dyke granite porphyry.

1. In thin section there are scattered ragged masses of greenish or yellowish green amphibole presumably occupying sites of pre-existing pyroxene. Very rare relics of such pyroxene have been observed.



Inset illustrates concept of the subsurface eccentricity of the biotite granite relative to earlier granite porphyry ring dyke.

Ike (1979)

2. Crystallization of amphiboles has been observed along cracks. This is presumed to be a late stage crystallization postdating the cracks i.e. after the rock had solidified and fractured.

3. The amphiboles found in the rock around or at this contact is lenght fast.

4. It has also been observed that in the recrystallized groundmass, there are independent crystals of Kfeldspars and albites.

5. Megascopically, the rock look very greyish in colour and different entirely in colour from the unaltered one.

There is also an increase in the coarseness of the groundmass of the rock at this area. The change observed in the granite porphyry at the contact can be explained, that the fluid phase associated with the cooling of the riebeckite granite intrusion was perhaps big enough to have affected a localized textural and mineralogical variation in the granite porphyry.

This has thus provided an evidence to the fact that riebeckite granite is a petrological agent.

CHAPTER FOUR

CORRELATION OF THE STRUCTURE AND PETROLOGY OF THE KUDARU RING COMPLEX

4.1 SUMMARY OF STRUCTURAL FEATURES

Most of the essential structural features which are characteristic of typical ring-complexes are represented in the Kudaru ring-complex. These are:

1. The perpheral ring-dyke which is oval in shape and encircles the component units of the complex.

2. The cone-sheets which are characteristically very thin, tangential in distribution and dip inwards. Individually, they are often very small in thickness and dip towards the centre of the complex at an angle of 30° to 60°.

3. The central pluton which occupies the central part of the complex. In Kudaru complex this outcrops in an oval or irregular pattern, elongating to cut the ring-dyke at the southern end of the complex.

4.2 SUMMARY OF THE PETROLOGICAL FEATURES

The ring-dyke can be petrographically distinquished into two rock types:

1. The granite porphyry in the South,
2. The quartz porphyry in the North.

The granite porphyry has a greenish grey colour. It is holocrystralline and has euhedral feldspar crystals within the groundmass which is granitic in texture. The rock is coarse grained. Minerals present in this rock include Quartz, alkali feldspar, pyroxene, amphiboles.

Quartz porphyry is very similar to the granite porphyry mineralogically, but petrographically they are different. Quartz porphyry contain phenocryst of quartz and alkali feldspars (usually orthoclose) in a microcrystalline or cryptocrystalline groundmass. The phenocryst are usually not so big as those found in the granite porphyry. They are also fragmented, thus giving it an ignimbritic texture. Minerals presents in the rock include fayalite, ca-rich pyroxene, amphibole.

The cone-sheets are made up of three different rock types. These are:

a) Granite porphyry,

b) Fine grained riebeckite granite

c) Pyroclastic rocks and rhyolites.

The granite porphyry found on the cone-sheet has precisely the same petrology as those found on the peripheral ring-dyke.

The fine grained riebeckite granite has a pinkish to milky white colour and is very fine grained. The crystals range in size from 0-1mm. The rock occasionally has some dark patches which are believed to be spherulites.

The remaining rock types on the cone-sheets are volcanic in origin and more of poorly melded tuff with dark and light band appearing on the rock. Also some are found to contain megascopically coarse spherulites. (Fig. 4.2a) Banded or flow rhyolites with light and dark band are also found on the cone-sheet. As usual they are very fine grained.

The central pluton is made up of one petrological units. The rock is pinkish to dirty white in colour and is generally coarse grained but decreases in coarseness towards the fringe with which it make contact with other rocks. It is holocrystalline and in the coarse grained portion, the crystals range in size from 3-5mm in size while in the fine grained area, the grain size range from 0-1mm.

4.3 CORRELATION OF THE STRUCTURE AND PETROLOGY OF THE KUDARU RING COMPLEX.

The Kudaru complex, being the first of its type to be discovered and mapped in Nigeria, had provided clues to the discovery of more ring complexes in Nigeria. However, following some recent findings in other complexes, (some of these findings being contrary to those earlier documented on Kudaru), the need to review the geology of Kudaru has therefore become obvious. However, this review has been done within a limited scope to clarify the existing knowledge of the complex. Following the review of its geology, the following points have been discovered.

1. The initial lithology of the peripheral ring-dyke is found to be made up of two initial rock types, contrary to the published view on the lithology of the peripheral ring-dyke by Bain (1934). These rocks units are the:

   1. Granite porphyry
   2. Quartz porphyry.

2. The cone-sheets on this complex can be classified into:

   a) Fine grained amphibole riebeckite granite,

   b) Granite porphyry,

   c) Rhyolitic rocks.

3. In contrast to the views of Bain (1934) that the Kudaru complex may never have witnessed a caldera formation and a complete absence of extrusive rocks (normally preserved by cauldron subsidence), the presence of extrusive rocks has been reported in more than one place by the writer. Like in many other neighbouring complexes of Banke, Ririwai, Ningi-Burra and Tibchi extrusive rocks have been reported. For example Jacobson and Macleod studied the Banke complex (1977) and reported the presence of a stretch of volcanic rock separating the granite and the ring-dyke in the north direction. Ririwai (Liruei) a very well studied complex is also reported to have volcanic rock preserved and almost completely sorrounding the central Biotite granite intrusion. Jacobson et al, 1958; Jacobson and Macleod, 1977). Turner and Bowden (1979) have recently mapped and studied the Ningi-Burra complex, and have recorded large volumes of extrusive volcanic rocks that each of the six centres

had followed the same cyclic order of magmatism. The presence of extrusive rock has also been reported in the Tibchi complex. Ike (1979). The presence of extrusive rocks in these complexes is suggestive of surface cauldron subsidence. From the foregoing it is apparent that the presence of extrusive rock in the Kudaru ring-complex suggest a surface cauldron subsidence which Bain (1934) could not suggest or found it negative.

The intrusion of the main central granite pluton beyond the confines of the peripheral ring-dyke frame work has several structural and petrological significance which may be explained as follow.

a) That the intrusion of the central pluton, beyond the confines of the ring-dyke is an indication of a change in the centre of magmatic activities analogous to the general migration tendency of Younger Granite ring-complexes.

b) The extension also has a tremendous effect on both the petrology and petrography of the pre-existing rocks at the immediate viscinity. It has hydrothermally altered those rock with which it has come into contact namely, the granite porphyry ring-dyke. This can be supported by information obtained from neighbouring complex where more precise technique and results have featured. An example is the work done in the Tibchi complex (Ike, 1979). Correlating the result it has been found that rock at the contact at the Kudaru complex have:

1. Scattered ragged masses of greenish or yellowish green amphiboles presumably occupying the sites of pre-existing pyroxene. Very rare relics of such pyroxenes have been observed.

2. Crystallization of amphiboles has been observed along cracks. This is believed to be a late-stage crystallization postdating the crack.

3. It has also be observed that in the recrystallized groundmass there are independent crystal of K-feldspar and albite.

4. The amphibole found in the rock around or at the contact is length fast.

5. There is a general absence of spherulites.

6. Rocks here are more coarse grained.

CONCLUSION

The geology of the Kudaru complex is not in anyway different from the geology of most other ring complexes, e.g. the Tibchi complex (Ike, 1979), Banke complex (Jacobson and Macleod, 1977) and Ririwai complex (Jacobson et al., 1958). Some of the apparent disparities as documented by Bain (1934) are unfortunate and may be due to insufficient field data at that time.

In the case of the hydrothermal alteration of the granite porphyry near the amphibole granite which truncate the former in the south, Ike (1979) was able to confirm similar petrographical data in Tibchi complex using mineral analysis by the electron microprobe, a facility that was non-existent in the days of Bain (1934).

The inadequate report on the cone-sheet and extrusive rocks may be due to insufficient field data. Suffice it to say that the geology of Kudaru complex is typical of the geology of most typical Nigerian Younger Granite ring complexes.

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