THE DISTRIBUTION OF MINOR DYKE- LIKE BODIES AROUNDZARIA

(PART OF ZARIA SHEET 102 S.W.)

THESIS SUBMITTED TO THE DEPARTMENT OF GEOLOGY, AHMADU BELLOUNIVERSITY,ZARIA IN PARTIAL FULFILLMENTOF THE AWARD OF BACHELOR OF SCIENCE DEGREE IN GEOLOGY

BY

MUFTAU ADEBISI DERE

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MY

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ABSTRACT

Outcrops of porpliyritic biotite granite in S.W. Zaria were traversed for the occurrence of minor dyke-like bodies.

A total of 176 pegmatites, 95 raicrogranite dykes and 110 quartz veins were located and their distribution and mineralogy were investigated.

These minor dyke bodies occur mainly in the porpliyritic biotite granite in the form of dykes, veins and veinlets. They maintain sharp contact with the host rock, cross-cutting relationship with one another and have regular trends i e .

Microgranites trends most NHW and NNE

Pegmatites trends mostly NNW and N - S.

Quartz veins trends mostly NW, E NE and N - S.

The cross-cutting relationship between each of the minor formations particularly microgranites and pegmatites suggests that there occurred several phases of pegmatite and micro-granite emplacement in the porphyritic biotite granite. Similarly, cross-cutting relationship between the minor formations suggests that the microgrnites are older than the pegmatites which are in turn older than quarts veins.

The presence of porphyritic biotite granite's xenolith in these dykes, their regular trends and the sharp nature of their contacts suggests that they were intruded into the

porphyritic granite. The sugary or aplitic texture of the microgranites suggests crystallization from melt under high pressure condition without formation of aqueous phase while the coarse texture of pegmatites also suggest crystallization from melt under low pressure in the presence of aqueous phase and slow cooling for the development of large crystals.

Similar observations were made by Jahns and Durham (1957), Ajibade (1977) and Hookah (1977) on Wamba pegmatites.

Judging by the siliceous nature of the quartz veins, and the age relationship of these dykes, there appeared a trend of Igneous activity marked by the emplacement of microgranites, pegmatites and quartz veins.

On the basis of these observations, a magmatic origin was proposed for the minor dyke like bodies and the porphyritic biotite granite.

CHAPTER ONE

INTRODUCTION

1.1 Aim Of The Project:

The primary aim of this project is to give students a practical training in the observation and interpretation of geological phenomena and to acquaint students with the method of writing a geological report.

It also aims at producing a report on the minor dyke-like bodies around Zaria that might further throw light on the genesis of Zaria granites.

Finally, it is an attempt to fulfil one of the requirements for the award of a Bachelor of Science degree in geology.

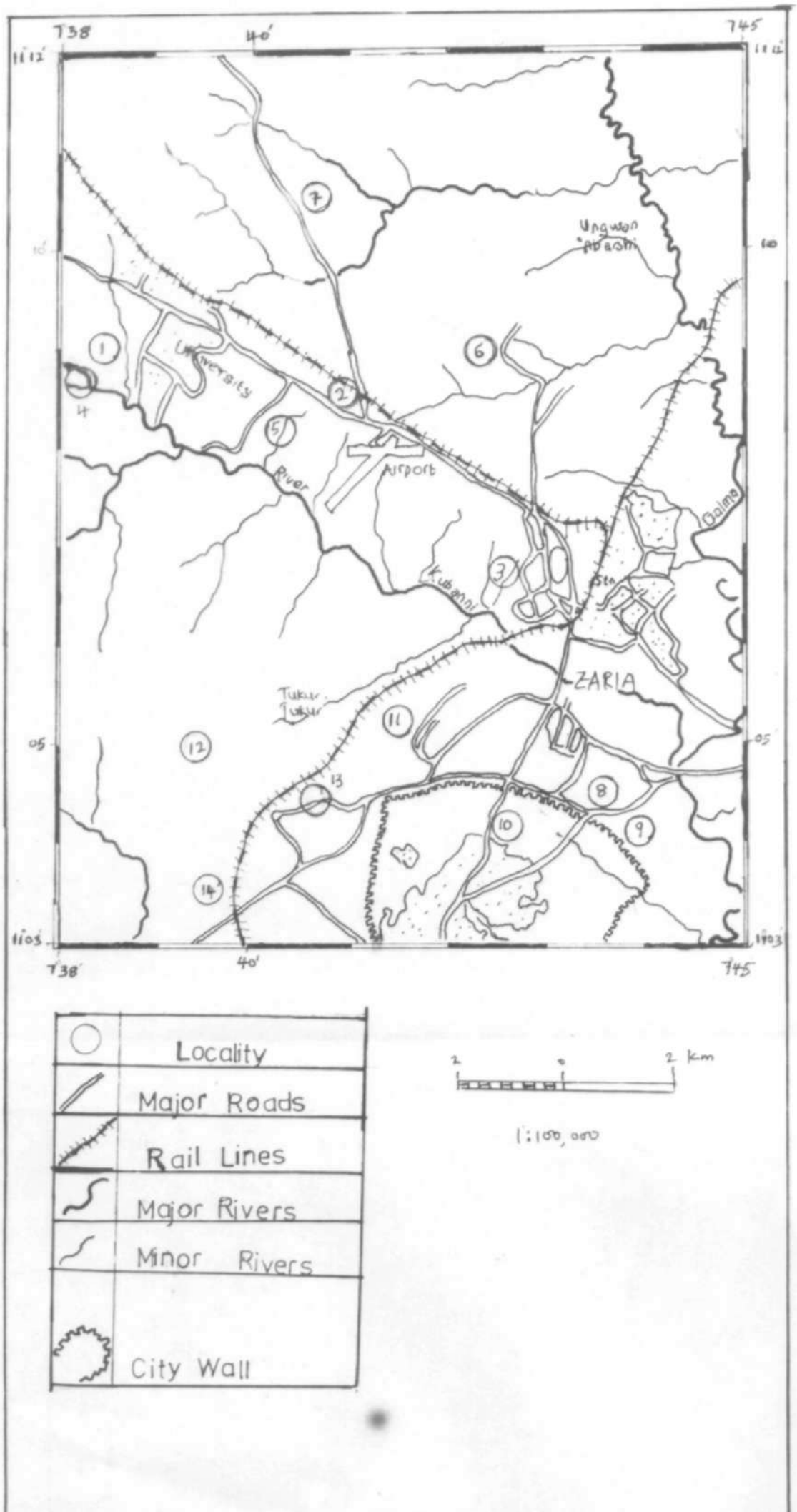
1.2 Location and Access:

The project area lies within longitudes 7° 38' to 7° 45'E and latitudes 11° 03' to 11° 12' N, covering an area of approximately 50 sq. km. It is part of sheet 102 Zaria SW. It is bounded on the eastern side by River Galma and the Ahmadu Bello University (Main Campus) on the North-Western side.

This area being densely populated has a net-work of motorable roads and is accessible by rail and even air (see Fig. 1.1). Most of the investigated outcrops lies within reasonable distances from the motorable roads and the few ones that are far away from such roads are connected by footpaths.

Fig. 1·1 LOCALITY MAP OF PART OF ZARIA

SHEET 102 SW 1:100,000



1.3 General Physiography

1.3-1 Relief and Drainage:

The area is a portion of the Zaria - Kano plains within which there are hilly features mainly of granitic rock inselbergs and few lateritic iron stone capped mesas. The inselbergs are scattered all over the area and they vary considerably in dimension and shape ranging from dome shaped to small whale backs. The highest elevation is observed on Kufena hill and is about 1,200m above sea level while the elevation of the general plain is about 800m above sea level.

The drainage system here focusses on River Galma, a major tributary of River Kaduna. It is being supplied with run-off from a drainage basin estimated at 6,822 sq.km. (Thorp 1970). The second major river is Kubanni which is itself fed by run-offs, flows South-Eastwards into River Galma which unlike its tributaries that are seasonal carries water throughout the year.

1.3-2 Climate and Vegetation

The climate of this area is such that there exist distinct wet and dry seasons. The dry season is practically rainless and is from October to March. Raining season, however, starts from April to September with heavy thunderstorm, the mean annual rainfall is 109 cm i.e. (mean of 1931-65

The seasonal rainfall makes its mark on the vegetation of the area such that in the raining season there exist extensive green savannah with few scattered trees while in the dry season, the green grasses turn to brown often yellow grasses with dry leafless trees. This is called the Northern Guinea Savannah zone a designation which implies a wood land vegetation type characterised by the presence of a tree which will if left undisturbed, form a moderately tall closed wood land on the interfluves with a grass cover.

1.4 Brief Review of Previous Work

Most of the previous works in this area centred mainly on groundwater investigation (Olowu 1967) and the geology of the basement complex. Among the previous workers on the basement geology, are Wright and McCurry (1970) who mapped Zaria sheet 102 SW on a scale of 1:50,000, and McCurry (1970) who mapped degree sheet 21 on a scale of 1:100,000 using photogeological interpretation with selected field traverses. Others include Webb (1972), Karofi (1972) and Ike (1974). All these workers only briefly mentioned the existence of the minor formations without investigating them fully.

The most detailed previous investigations of the minor dyke-like bodies are the works of Olatunji (unpublished) on the amethyst belt (personal communication) and his recent paper

on the "Structural setting and genetic signifance of minor dyke-like bodies in S.W. Baria".

1.5 Method and Scope of Present Work

This investigation was centred on the distribution and mineralogy of the minor dyke-like bodies, their field relationships and structural orientation which has hitherto been neglected in previous works except that by Olatunji (personal communication) A geological map on a scale of 1:50,000 drawn by Wright and McCurry (1970) was used as basemap for the location of outcrops and recording of certain structural data.

The field approach was to visit outcrops and to observe their geological setting mineralogy and textural features with special regards to the minor dyke-like bodies. On each outcrop traverses were taken such that the maximum number of the minor formations were observed i.e. by taking traverses perpendicular to the general strike direction of the minor dyke-like bodies. Samples of the minor dyke-like bodies and that of the porphyritic biotite granite were collected (appendix 1) and described for most localities especially where there exist either mineralogical or textural variation to the known general trend.

Petrographic description was based on macroscopic observation and staining test. Four samples of pegmatites were selected for stain test. Polished surfaces of the samples were

etched using concentrated hydrofluoric acid and then stained by immersion in a saturated solution of sodium bicarbonate after which the minerals exhibit different colours i.e. k-feldspar becomes yellow, plagioclase milky white and quartz colourless. From the stained slabs, modal analysis of the minerals was performed.

CHAPTER TWO

GENERAL GEOLOGY

More than half of the surface area of Nigeria is covered by the basement complex rocks of paleozoic to pre-cambrian age, which are represented by a series of older metasediments and gneisses believed to be of Birrimian age McCurry (1970).

Early workers believed that the basement has been through two tectono-metamorphic cycles (Oyawoye, 1959), so that they have been largely converted to migmatites and granite-gneiss. Younger metasediments believed to be upper proterozoic in age were deposited on this granitised basement and folded along with it during the Pan - African Orogeny.

Intrusive into both the basement rocks and the younger supra crustal cover is a series of basic, intermediate and acid plutonic rocks known as the older granites. A widely distributed suite of the older granites in the project area is the porphyritic biotite granite.

2.1 Nature and Distribution of Major Rock Groups

2.1-1 Porphyritic Biotite Granite

More than 50% of the project area is covered by the porphyritic biotite granite (see fig. 2.1). Though the rock is covered in many places by a thick superficial deposit,

exposures are generally good and continuous outcrops are common sometimes in form of isolated hills, inselbergs and low whale backs. The rock has a coarse porphyritic texture with large white to pink prismatic microcline (averaging 2cm but sometimes up to 4cm in length) embedded in a finer granitic groundmass. The rock shows distinct lineation defined by parallel allignment of the feldspar phenocrysts and black flakes of biotite. The rock is essentially granitic in composition and mineralogy include quartz, k- feldspar, plagioclase and biotite. The lineation of the rock is in the direction 010° - 018° and certain dark grey to black xenoliths believed to be relicts of the crystalline basement are also alligned in approximately North-South direction.

The rock contains several phases of microgranites and pegmatites as evidenced by their cross-cutting relationships. Similar observation have been made by Wright and McCurry (1970), Rahaman (1975) and Kayode (1975) in his study of Igbo-Ora complex, S.W. Nigeria. The rock is fractured (see plate II) and often faulted as evidenced by the presence of sticken-sides observed in the field. Further discussion on the nature and characteristics of the fractures is in chapter four. A contact of the porphyritic biotite granite and the biotite gneiss was observed in the field around Kufena hill

Fig. 2·1 GEOLOGICAL MAP OF PART OF ZARIA

SHEET 102 SW 1: 100,000

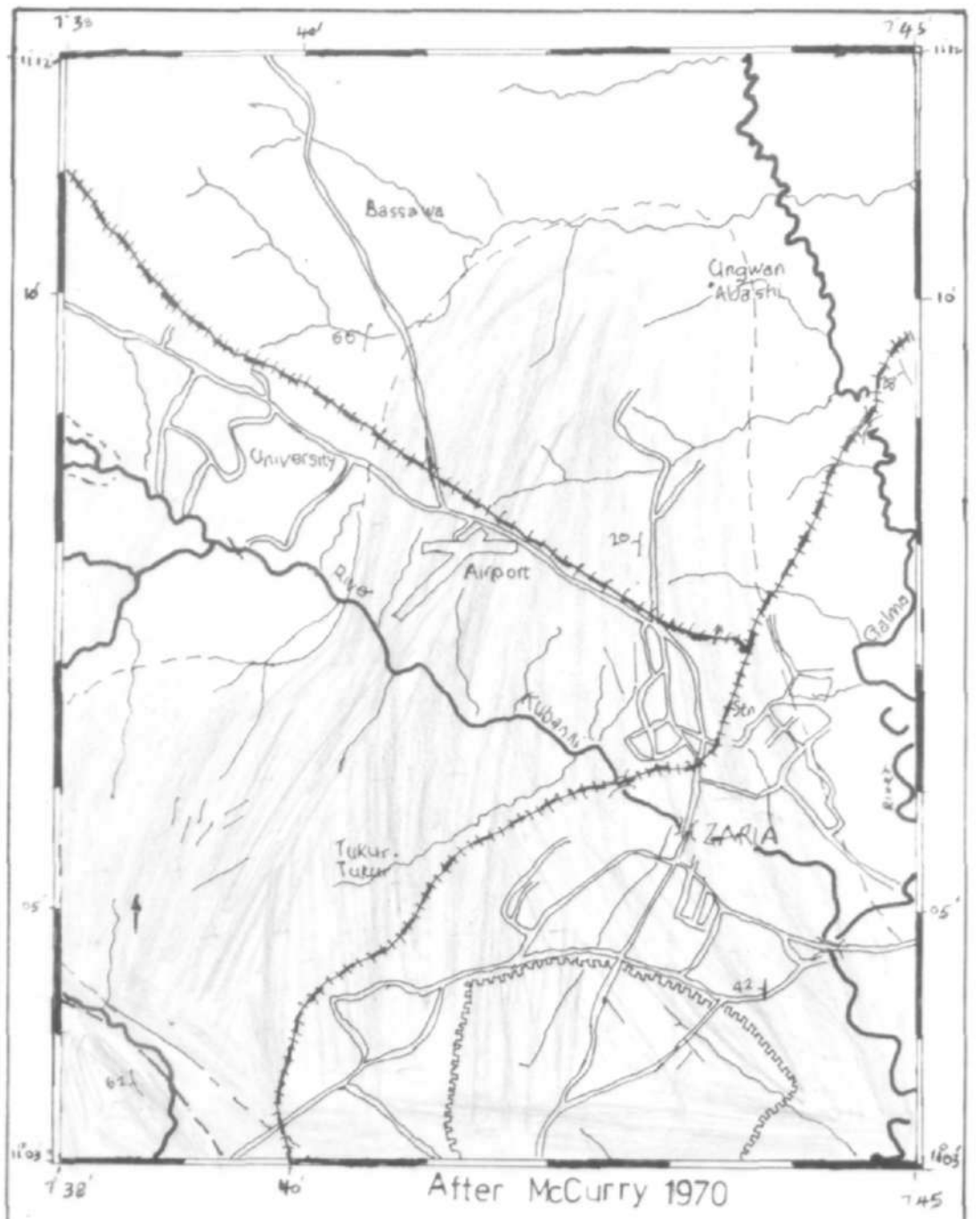


TABLE 1. LIST AND DESCRIPTION OF LOCALITIES

LOC. NO.	LOCALITY WITH APPROX. REF. GRID	MAP SHEET	TYPE AND DESCRIPTION OF HOST ROCK	MICROGRANITE DYKES	PEGMATITES	QUARTZ VEINS	PROMINENT JOINTS	XENOLITH	SLICKEN SIDES
1	11°9.2'N 7°38.3'E Bt outcrop near water tank	102 SW	Microgranite elongated in the N-S direction measuring 200m by 15m	1	1	4	3	Contains xenolith of porphyritic biotite granite	✓
2	11°8.4'N 7°41.2'E Kano junction outcrop Kano/ Funtua Road		Porphyritic biotite granite that is dome shaped with good exposure one to quarrying.	8	19	4	6	contains amphibolite	✓
3	11°07'N 7°42.3'E Hanwa Outcrop near Primary School		A large body of porphyritic biotite granite is the form of an elongated dome and is being quaried on the Northern end.	4	5	2	6	contains amphibolite	✓
4	11°9'N 7°38.2'E River Valley otc		A badly weathered biotite gneiss outcropping only on the river bed. 500m by 20m		3	2			
5	11°71'N-1° 7°40.3'E River Valley otc near Ungwan Mallam tsofo		Porphyritic biotite granite exposed along a river channel extending over 100m and width about 30m.	8	10	6	3		✓
6	11°8.9'N - 7°42.6'E Otc near Ungwan Abarshi		A dome shaped porphyritic biotite granite with average radius of about 250m.	7	13	2	14	contains amphibolite	✓
7	11°10.4'N - 7°40.7'E Bassawa Outcrop		Microgranite dyke exposure near Bassawa village striking approx. N-S measuring 70m by 30m	1	7	2	10		✓

Table 1 - contd.

LOC. NO.	LOC DESCRIPTION	MAP SHEET	TYPE AND DESCRIPTION OF HOST ROCK	MICROGRANITE DYKES	PEGMATITE	QUARTZ VEINS	PROMINENT JOINTS	XENOLITH	SLICKEN SIDES
8	11°703.5'N 7°43:75'E		Porphyritic biotite granite bathetith elongated in the E-W direction measuring 250m by 150m and height about 10m above the general terrain	9	16	6	4		✓
9	11°703.3'N 7°43.75'E		A porphyritic biotite granite bathetith measuring 150 by 50 by 7m. It is being quaried all over	6	21	10	8		✓
10(i)	11°703.3'N 7°43.25'E		Large dome shaped porphyritic biotite granite measuring 200m-80m-10m broken all over into large boulders	6	5	12	2		
(ii)	500m SE of Zaria City Prison		Large porphyritic biotite granite	6	14	5	6		✓
(iii)	400m SE of Zaria Prison		Porphyritic biotite granite exposure in the form of a whole back	4	6	1	7		✓
(iv)	500m SE of Zaria City Prison		Porphyritic biotite granite outcrop with N-S elongation measuring 100m by 15m by 2m	5	6	2	14		✓
11(i)	11°05.3'N 7°41.5'E		Porphyritic biotite granite which is dome shaped measuring approx. 150m radius and about 20m above the terrain	6	7	10	6		
(ii)	100m W of		Porphyritic biotite granite also dome shaped	9	11	7	6		

Table 1 - contd.

LOC. NO.	LOC DESCRIPTION	MAP SHEET	TYPE AND DESCRIPTION OF HOST ROCK	MICROGRANITE DYKES	PEGMATITE	QUARTZ VEINS	PROMINENT JOINTS	XENOLITH	SLICKEN SIDES
12	11°05'N 7°39.5'E		A very large prophyritic biotite known as Kufena hill	11	24	17	37	Amphibolite	✓
13	11°04.5'N 7°40.5'E		A large whale back of porphyritic biotite granite measuring 150m by 50m	4	8	16	22	Amphibolite	✓
14	11°03.8'N 7°40.5'E		A dirty brown heterogeneous laterite	-	-	2	-		
				95	176	110	154		

and the contact appeared very sharp with slight plastic deformation of the biotite gneiss.

In most of its exposures, the porphyritic biotite granite is being weathered mainly by exfoliation, insolation and chemical weathering.

Around most of the outcrops, sheets of rocks breaking into flakes are common and decayed parts where the feldspars are already being kaolinized.

2.1-2 Biotite Gneiss

Outcrops of biotite gneiss are not very common in the project area, but they were located in the upper part of River Kubanni Loc.4 (see table 1) and South-Eastern part of Kufena hill. The observed outcrop is distinctly foliated with gneissose texture. It is dome-shaped and is in contact with the porphyritic biotite granite already described above. It also contains pegmatites (tourmaline bearing) and quartz veins which are largely discordant to the foliation and maintains sharp contact with it.

2.1-3 Laterite

Laterites are also common here and they are believed to be erosional remnants of a laterite sheet on an extensive peneplain described by Du Preez (1956) as being possible pliocene age. In locality (14) where Amethyst was found, the

laterite is dirty brown in colour with small white specks of kaolinised feldspar and has homogeneous texture. This is most probably a product of "in situ" lateritization of granite. Just close to this very area, there is a laterite with heterogeneous texture defined by large grains of quartz embedded in a finer yellow to brown coloured ferrugenised matrix. This is an indication that the laterite was not formed 'in situ' rather it must have been transported.

These laterites have been distinguished and described as the older and younger laterites by Wright and McCurry (1970).

CHAPTER THREE

THE MINOR DYKE-LIKE BODIES

The minor dyke-like bodies in this report are micro-granites, pegmatites and quartz veins which are closely associated with porphyritic biotite granite. Previous workers like McCurry (1970) recognised the fact that several phases of pegmatite and microgranite emplacement is associated with the Zaria granites. These minor dyke-like bodies are described individually with special reference to their distribution, mineralogy and textural relationships. On the basis of field evidence, attempt have been made to reconstruct their mode of origin and emplacement.

3.1 The Microgranite Dykes

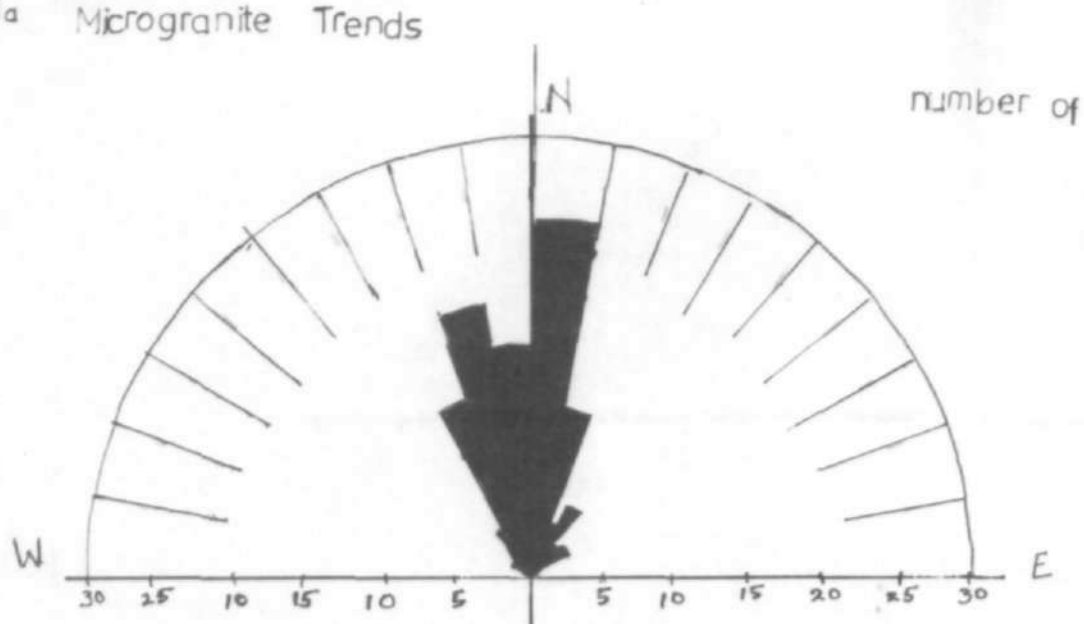
3.1-1 Distribution and field Relationship

The distribution of the microgranite dykes will be considered under three sub-headings viz. (a) their spatial distribution (b) structural trend as shown on rosette diagram and (c) plot of poles to fracture planes infilled by microgranite dykes.

Fig·3.1

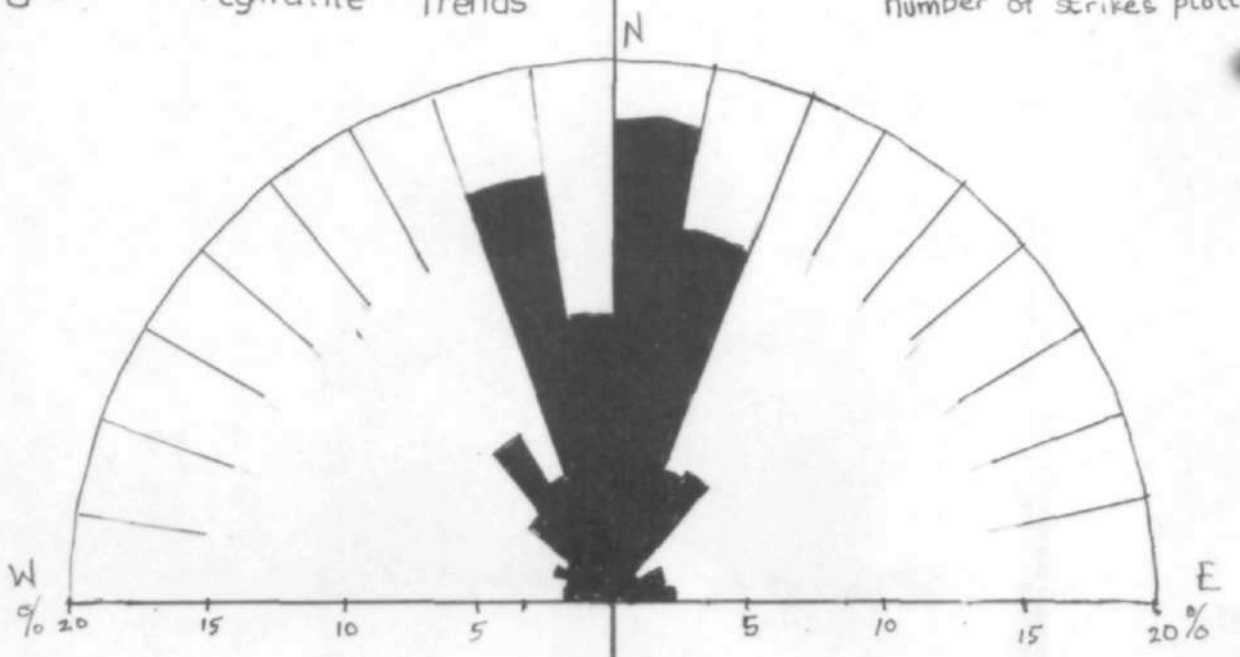
Rosette Diagrams of minor dyke like bodies around Zaria

Fig·3·1a Microgranite Trends



number of strikes Plotted = 95

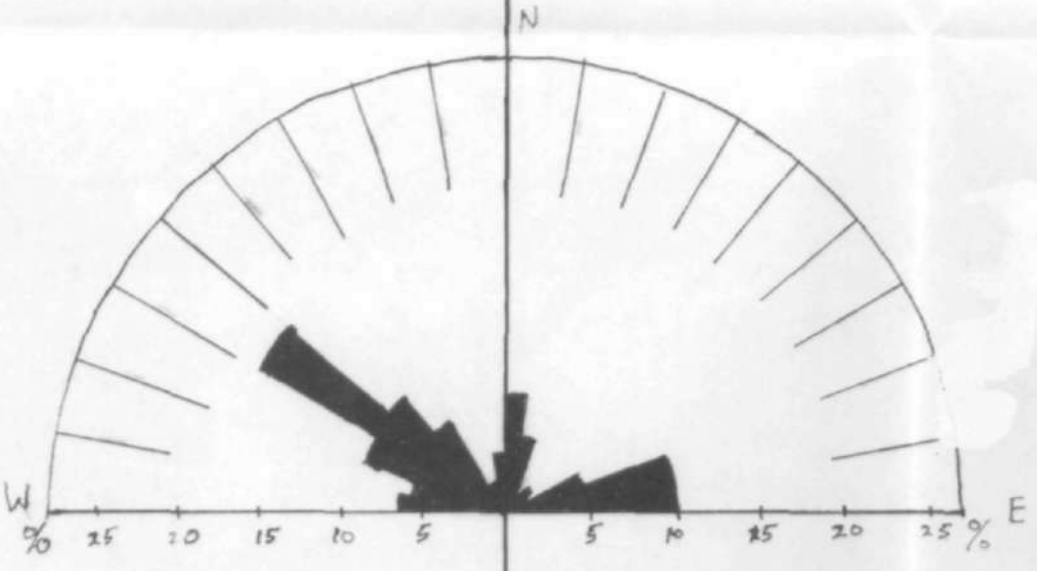
Fig·3·1b Pegmatite Trends



number of strikes plotted = 176

Fig 3·1c

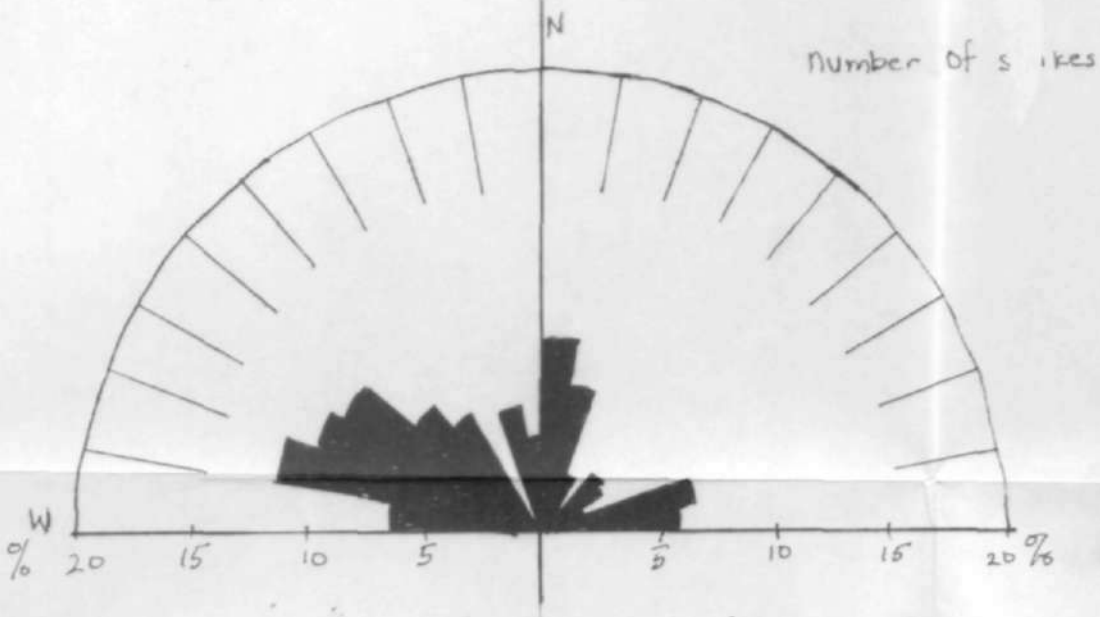
Quartz vein Trends



number of strikes plotted = 110

Fig·3·1d

Gaping joint Trends



number of strikes plotted = 154

(a) Spatial Distribution of the microgranite dykes

Microgranite dykes are widely distributed in the project area and apart from locality 14, they occur in all the other localities (see fig. 1.1). The number of the microgranite-dykes found in the different localities vary (see table 1) and in few of the localities i.e. (loc.1), the only outcrop is a big microgranite dyke. On the whole, ninety five microgranite dykes were located in the field, and they are generally confined to areas of the porphyritic biotite granite as few traverses on the laterites did not reveal the occurrence of microgranite dykes.

(b) Structural trend as shown on rosette diagram

The rosette diagram (fig. 3.1a) of the microgranite dykes have two major trends, namely 340° - 350° and 000° - 010° corresponding to NNW and NNE trends respectively. Fig. 3.1a also shows no microgranite dyke trending E - W. There are two possible explanations to this observation.

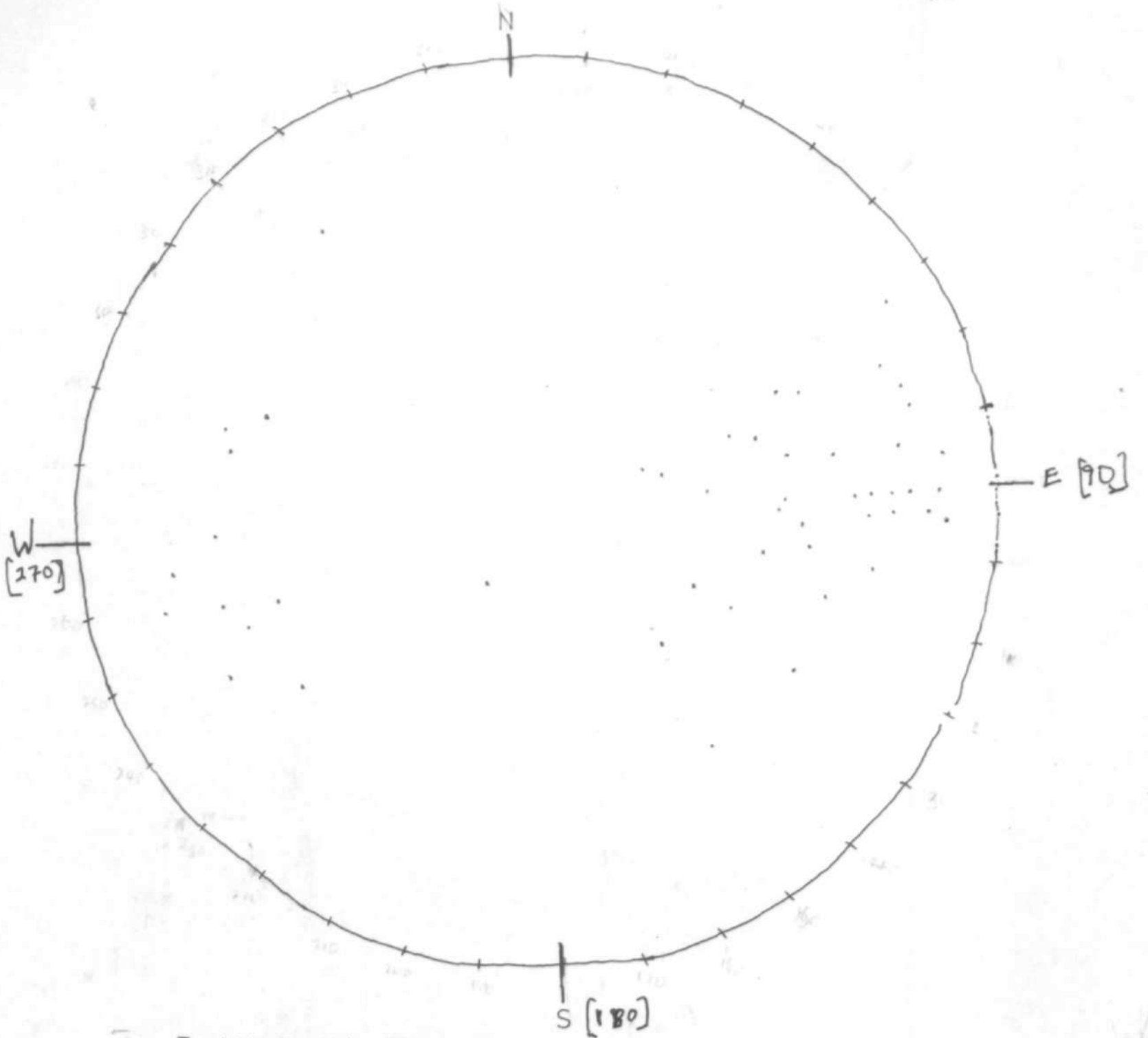
i) That the fractures infilled by microgranite dykes were produced by E-W trending forces which are possibly due to the Pan-African Orogeny.

ii) That the fractures were produced by contraction due to the cooling of the magma that formed the porphyritic biotite granite. The non-existence of E - W trending microgranite dykes could also mean that at the time of emplacement of the microgranites, there exist no E - W trending fractures.

Fig. 3.3

PLOT OF POLES TO FRACTURE PLANES

INFILLED BY MICROGRANITE



Total No Of Pole Plots = 54

One strike/dip reading is represented by a point.

(c) Distribution in space using pole plots

The plot of poles to the fracture planes infilled by microgranite dykes (see fig. 3.3) indicates concentration of poles between the NE and SE quadrants especially their boundary, and the pole plots are far away from the centre of the net. The interpretation is that most of the microgranite dykes are trending NNE and NNW, and they are dipping at high angle predominantly Westwards although there exist few that are dipping Eastwards.

The only possible explanation is that the fractures infilled by microgranite dykes are mostly dipping at high angle Westwards and trend mainly NNE and NNW.

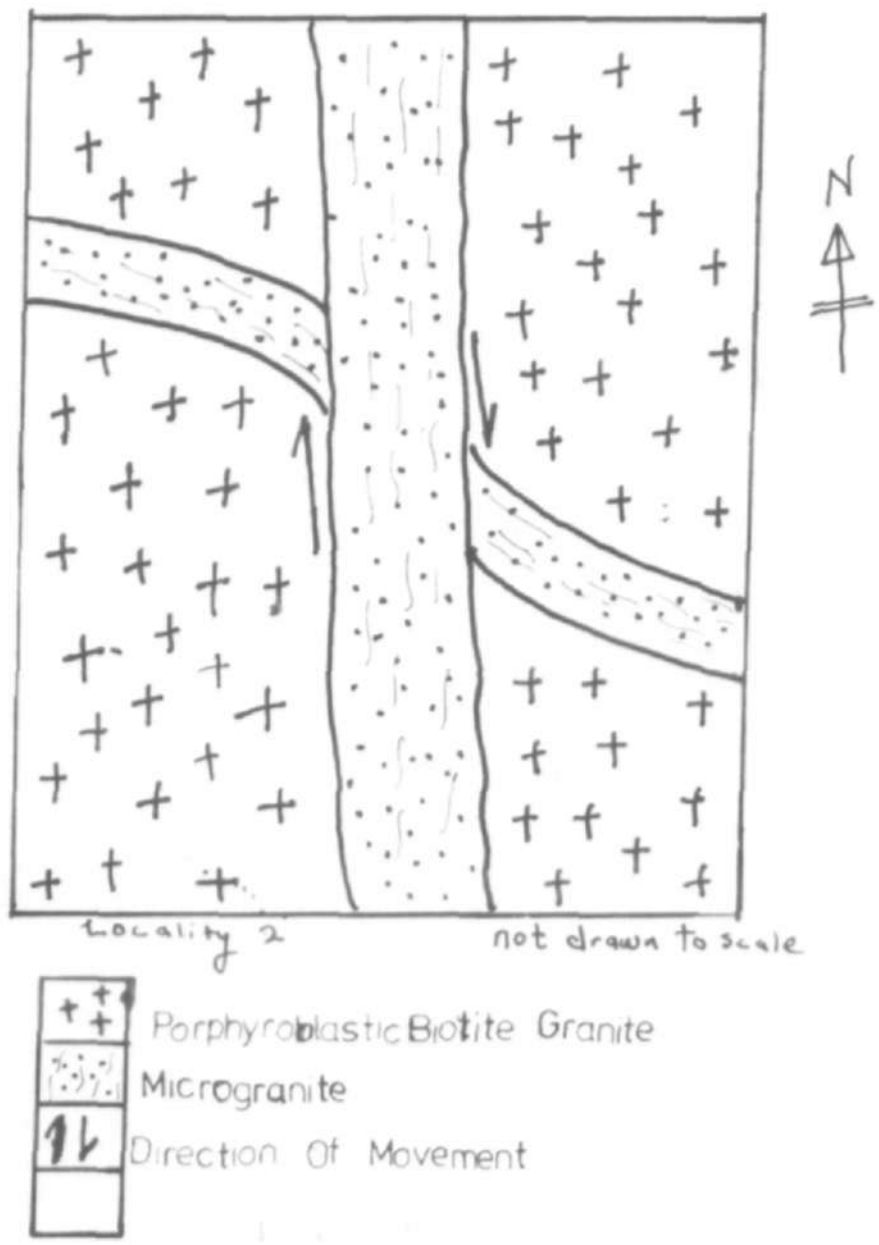
3.1-2 Field Relationship

The microgranites usually occur in the porphyritic biotite granite in form of regular dyke-like bodies. They also commonly maintain sharp contact with the porphyritic biotite granite. Their widths extend from few centimeters to about 15m (see appendix 2) and length up to 150m was observed in the field Loc. 1.

Xenoliths of porphyritic biotite granite are common in the microgranite dykes i.e. loc. 1 and in most cases the xenoliths also have sharp boundaries with the dykes although the lineation of minerals in the xenoliths are often not in the same direction as that of the porphyritic biotite granite host rock.

Fig. 3.2

Schematic diagram of a younger microgranite dyke cutting across an older microgranite dyke

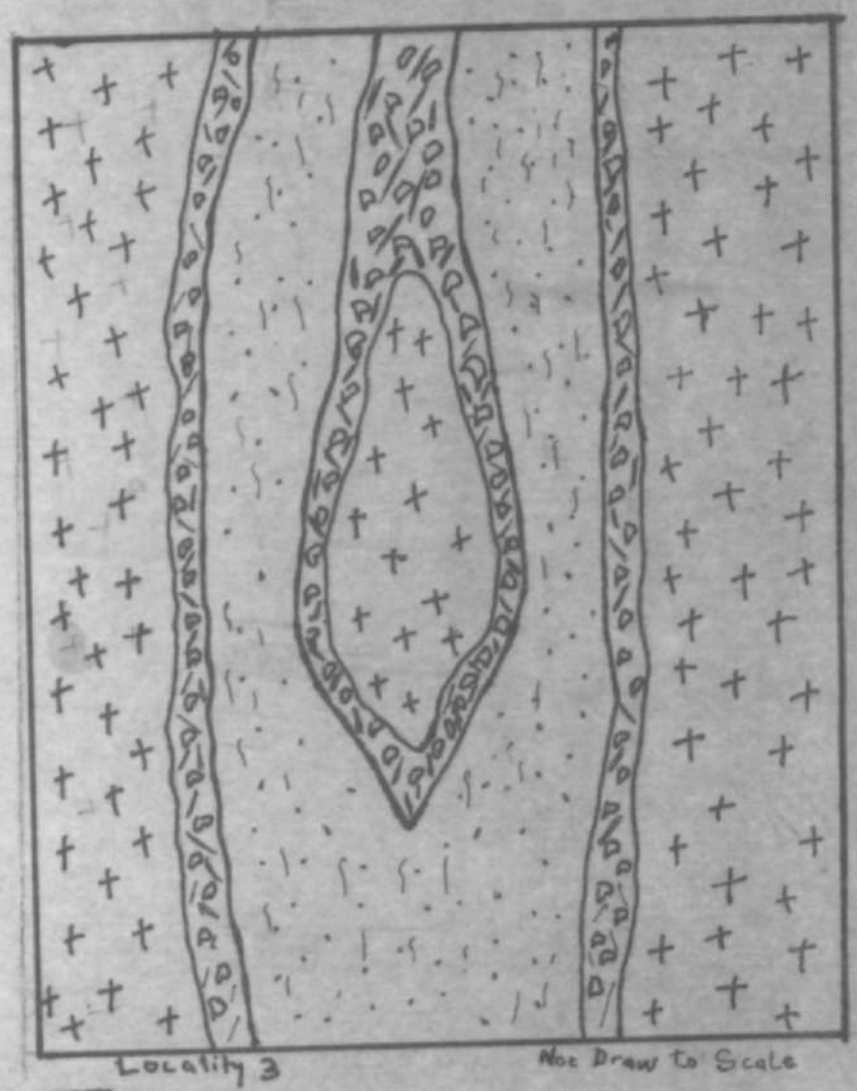


The microgranites usually, are found parallel to one another, but they often maintain cross-cutting relationship with one another (see fig. 3.2). They are also commonly found together with pegmatites either occupying the same fracture or the pegmatites cutting across the microgranites. A particular interesting observation is the occurrence of a biotite rich pegmatite at the margin of a xenolith of the porphyritic biotite granite in a microgranite dyke (see fig. 3.4).

The occurrence of a xenolith of the porphyritic biotite granite in a microgranite dyke suggests that the later must have been intruded perhaps forcefully into the later such that it breaks off part of the host rock in the process of its emplacement. The fact that pegmatites were found cutting across the microgranite dykes also suggest that the pegmatites are younger than the microgranites i.e. the emplacement of the pegmatites must have been after the emplacement of the microgranites.

The observed occurrence of biotite rich pegmatite at the contacts of a microgranite dyke can also be explained thus: That the microgranite broke up part of the host rock during its emplacement which remained as a xenolith and later pegmatite intrusion utilized the weak zones i.e.

Fig. 3.14 Schematic diagram showing spatial relationship between a microgranite and pegmatite



Note the xenolith of host rock in the pegmatite

the contacts, between the host rock and the microgranite, while the enrichment of biotite might be due to reworking or partial digestion of the xenolith.

In most localities where microgranites and quartz veins exist, the quartz veins usually cut across the microgranite dykes and sometimes with little displacement. This is also an indication that the quartz veins are younger than the microgranites.

3.1-3 Mineralogy

Microgranites around Zaria are light grey in colour. They are characterised by monotonous sugary or aplitic texture with medium grained crystalline aggregates of plagioclase, microcline and quartz closely interwoven and tiny flakes of biotite defining a poor lineation. Few of these dykes appear pinkish and this has been attributed to the abundance of k - feldspar McCurry (1970).

The mineralogy of the microgranites essentially include quartz, k - feldspar plagioclase and biotite which are described individually below.

K - feldspars:- are the most abundant minerals and are pinkish to creamy white in colour, grain size ranges from submicroscopic to about 5mm and are commonly intergrown with plagioclase, quartz and biotite forming a sort of graphic texture.

Plagioclase:- usually creamy white in colour and grain size usually less than 5mm. They are common in all the microgranites but their proportion vary.

Quartz:- usually colourless and occur in crystalline aggregates as well as intergrowth in other minerals. Size ranges from sub-microscopic to about 5mm.

Biotite:- tiny flakes of biotite exist in all the microgranites and are less than 1mm thick. They are oriented in the direction of the microgranite's strike, thus defining a sort of lineation.

3.1-4 Comments on Mode of Origin

Many attempts have been made to explain the origin of microgranites basically from their composition and mode of occurrence Krauskpoff (1967). The monotonous sugary or aplitic texture was said to have been formed or produced under high pressure condition that prevent the formation of an aqueous phase.

In their famous experiment designed to duplicate the conditions of pegmatite formation, Jahns and Burham (1957) heated a mixture of quartz, k-feldspar and Na- feldspars to melting with a measured amount of water slightly less than that necessary for saturation, and the solution was left to cool slowly. It was observed that crystallization from

homogeneous liquid be ins with separation of a fine-grained quartz-feldspar aggregate on the walls of the container. In the same experiment, it was found that if the pressure is high enough at all times to prevent the formation of an aqueous phase, the crystalline product has the fine grained texture of aplite throughout. Although the mixture used in this experinent differ in one respect from that obtainable in natural condition in that all natural volatiles like Hcl, HF etc., that are characteristic of magmas are not present, nevertheless, the similarity of their mixtures to natural residual fluid is sufficiently close to make a generalization reasonably safe that aplites represent a residual melt which crystallized without the separation of an aqueous phase.

It can be reasoned from the experiment described above that the microgranites here are the product of the residual melt which formed the porphyritic biotite granite. They might have been emplaced under high pressure condition without formation of aqueous phase, cooled and solidified in the NNE, and NNW trending cracks produced by stresses in the porphyritic biotite granite. The idea about the existence of more than one phase of microgranite emplacement can therefore be accounted for, by the resurgence of the residual melt due to variation in

internal pressure at depth. Their constant association with pegmatites also support this idea while the presence of xenolith of the porphyritic biotite granite commonly found in the microgranite dykes is suggestive that the microgranites have a magmatic origin hence in agreement with the above experiment of Jahns and Burham.

3.2 Pegmatites

3.2-1 Distribution and field relationships

The distribution of pegmatites is treated here under three sub-headings namely: (i) Their spatial distribution, (ii) Structural trend as shown on rosette diagram and (iii) Distribution in space using pole plots.

i) Spatial distribution of the pegmatites

Pegmatites are widely distributed in this area, as can be seen from the number of pegmatites found in each locality (see table 1). Apart from locality 14, pegmatites occur in all the other localities and they are confined to areas of granitic intrusions. On the whole, 176 pegmatites were located in the field and this give an approximate density of three pegmatites per square kilometer.

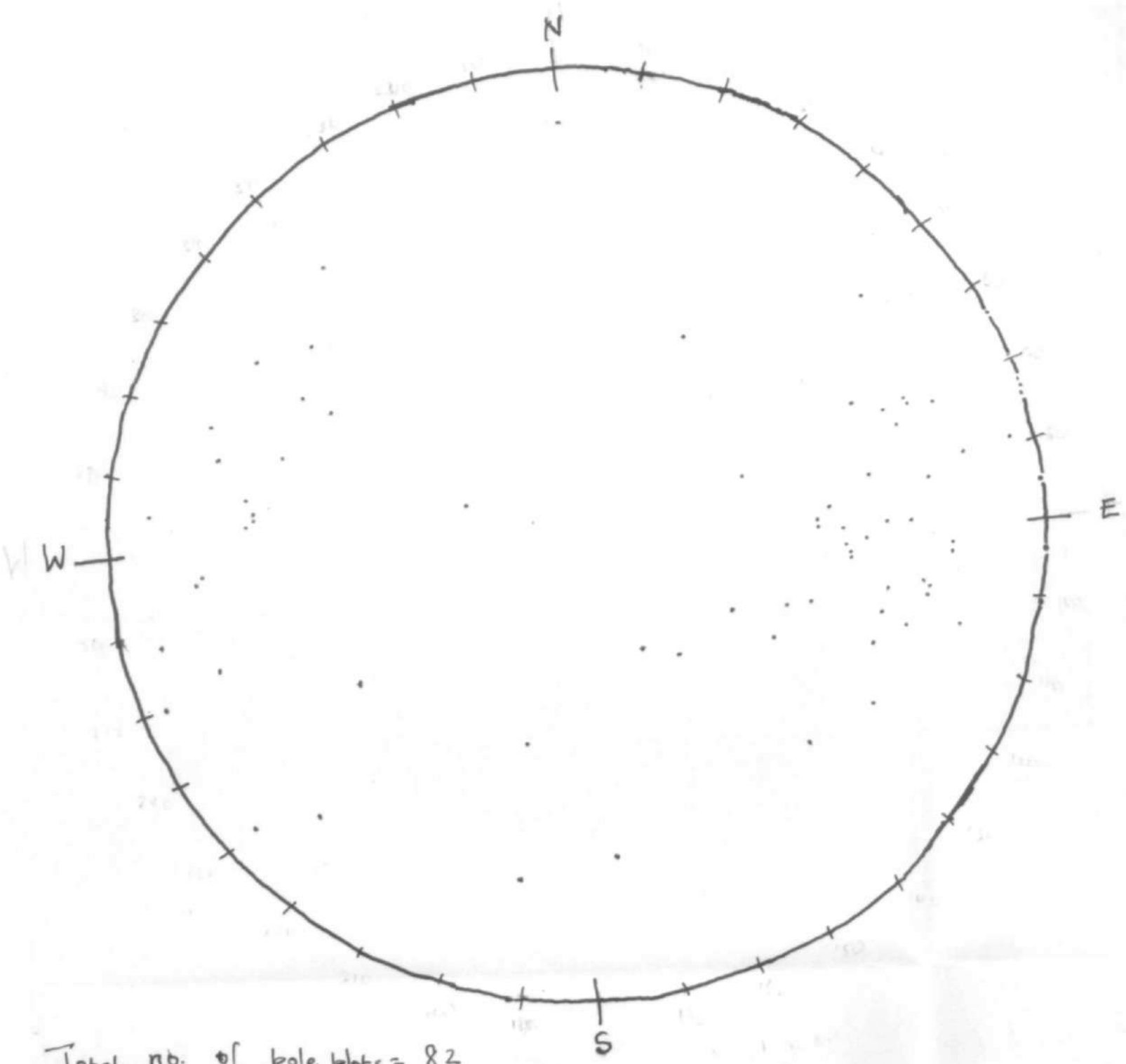
ii) Structural trend as shown on rosette diagram

The trend diagram (fig.3.1b) shows two major trends viz. 000^{o}-010^{o} and 000^{o}-340^{o} corresponding to NNE and NNW

Fig. 3.6

PLOT OF POLES TO FRACTURE PLANES

.INFILLED BY PEGMATITE



Total no. of pole plots = 82

One strike/dip reading is represented by a point.

trends respectively. The observed trends implies that the fractures infilled by pegmatites have the above mentioned trends and this is the reason why most of the pegmatites are either concordant or slightly discordant to the foliation of the porphyritic biotite granite. It is worth noting that the minor peaks i.e. 290° - 300° and 080° - 090° can possibly be older than the major trends of the pegmatites which might have defaced the older ones. This also suggest more than one phase of pegmatite emplacement.

iii) Distribution in space using pole plots

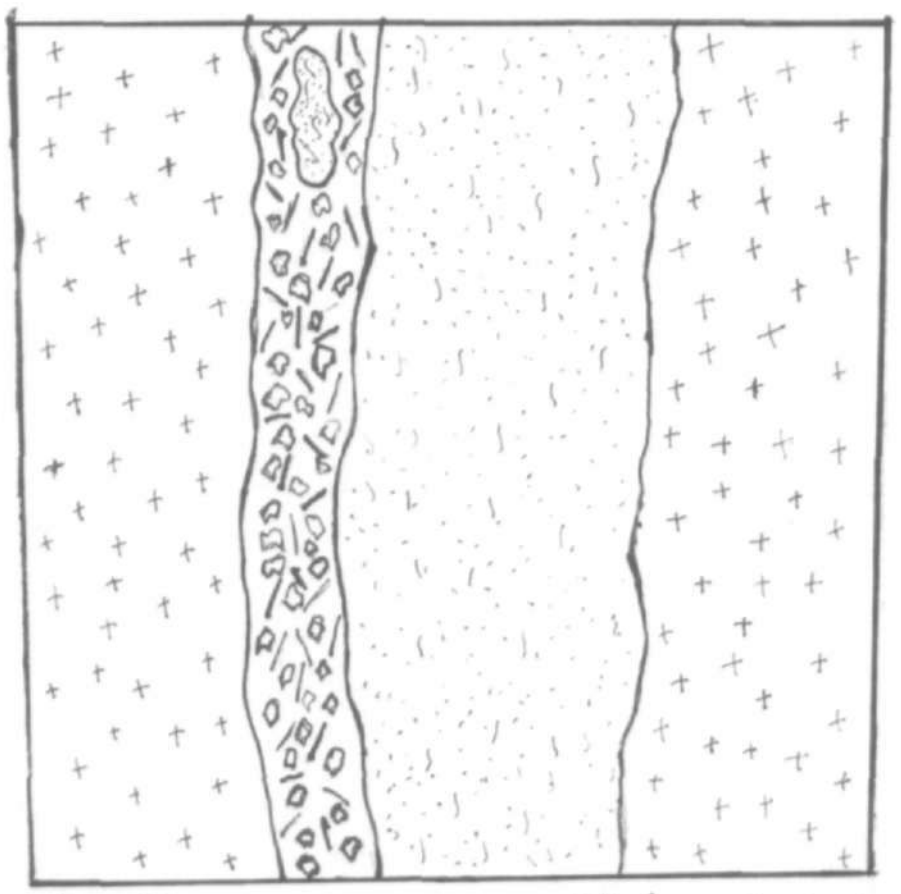
The plot of poles (fig. 3.6) to the fracture planes infilled by pegmatites shows concentration of the poles as follows:

a) Far from the centre of the net i.e. close to the big circle especially the eastern side;

b) Most of the poles are concentrated between the NE and SE quadrants. The implication is that most of the pegmatites have high angle dips generally between 45° to 70° westwards and less commonly eastwards while the predominant strikes are NNE and NNW. This is about the most reliable information from which we know the behaviour of the pegmatites at depth.

It then means that the fractures infilled by pegmatites are trending mostly NNE and NNW and this agrees closely with the Pan - African Orogeny. The pattern of the joints infilled

Fig. 3.5 Spatial Relationship Between a Microgranite And Pegmatite



by the pegmatites according to McCurry (1970) conforms with a single episode of fracturing such as might be expected to accompany uplift, cooling and contraction of rocks.

3.2-2 Field Relationships

Pegmatites in SW Zaria have a characteristic coarse grained texture and they occur in form of dykes, veins and veinlets within the porphyritic biotite granite. The pegmatites maintain sharp contact relationship with the porphyritic biotite granite. Quite often, they occupy the same fracture with the microgranites, (fig. 3.5), and sometimes the pegmatites cuts through the microgranites (see plate 1). Pegmatites occur not only in porphyritic biotite granite but also in some large microgranite dykes i.e. loc. 1, (see plates 3 and 6).

Figure 3.5 shows the occurrence of a microgranite xenolith in a biotite pegmatite. This observation suggest that the pegmatite is a likely later intrusion into the porphyritic biotite granite emplaced along the weak zone or fracture infilled by the microgranite.

Cross-cutting relationship also exist among the pegmatites particularly between the tourmaline bearing and biotite bearing pegmatites. In locality 10ii, a tourmaline pegmatite veinlet cut through a biotite pegmatite, an indication that the later

Table 2 - ANALYSIS OF PEGMATITES FROM DIFFERENT LOCALITIES

LOC. NO.	LOCALITY DESCRIPTION	MINERALOGY				
		QUARTZ	FELD-SPAR	BIO-TITE	MUSCO-VITE	TOUR-MALINE
1	11°9.2'N 7°38.3'E B.Z. Outcrop near water tank	/	/	-	-	/
2	11°8.4'N 7°41.2'E Kano road junction outcrop	/	/	/	-	-
3	11°7'N 7°42.8'E Hanwa Outcrop	/	/	/	-	-
4	11°9'N 7°38.2'E Outcrop in a river valley BZ area and area F	/	/	/	/	/
5	11°7.1'N 7°40.3'E Outcrop in a river valley near Ungwan Mallam tsofo	/	/	/	/	-
6	11°8.9'N 7°42.6'E Outcrop near Ungwan Abarshi (Military Shotting site)	/	/	/	-	/
7	11°10.4'N 7°40.6'E Bassawa village outcrop	/	/	/	-	-
8	11°3.5'N 7°43.75'E Kongo outcrop	/	/	/	-	-
9	11°3.3'N 7°43.75'E Kongo outcrop near Zaria City wall	/	/	/	-	-

Table 2 Contd.

LOC. NO.	LOCALITY DESCRIPTION	MINERALOGY				
		QUARTZ	FELD-SPAR	BIO-TITE	MUSCO-VITE	TOUR MALINE
10i	11°3.3'N 7°43.25'E Zaria City outcrop	/	/	/	-	-
*10ii	11°3.3'N 7°43.25'E	/	/	/	-	/ *
11	11°0.55'N 7°41.5'E Tukur-Tukur outcrop behind Barewa College (with water tank)	/	/	/	-	-
12	11°05'N 7°39.5'E Kufena hill	/	/	/	-	-
13	11°4.5'N 7°40.5'E Wusasa Outcrop near Rail line	/	/	/	-	-
14	11°3.8'N 8°40.5'E Unjwati Bala Anethyst	/	-	-	-	-

*Only one pegmatite contain tourmaline, all others are biotite pegmatite.

is older than the former. This observation also suggest that there exist more than one phase of pegmatite emplacement.

3.2-3 Mineralogy and Classification of the Pegmatites

Apart from megascopic description of hand specimen in the field, four selected samples of the pegmatites were stained. The major minerals recognised are described here under.

K- feldspar:- pink coloured potassium feldspar is the most abundant mineral in Maria pegmatites. This was realised from modal analysis of four stained samples (see table 3). They are usually more than 40% of the pegmatites by volume. They occur as crystalline aggregates ranging from 1cm to about 7cm across. Intergrowths of quartz and plagioclase are quite common in them.

Plagioclase:- usually occur with k-feldspar and are creamy white in colour. Grain size ranges from 1cm in k-feldspar rich pegmatites to 5cm in plagioclase rich pegmatites.

Biotite:- thin books of biotite are commonly observed in Maria pegmatites. They have golden yellow lustre and are mostly embedded in k-feldspar - quartz intergrowths. Grain size ranges from 1cm to about 4cm. Large flakes are up to 6cm in length, and do occur in some biotite rich pegmatites.

TABLE 3 - MODAL ANALYSIS OF PEGMATITES AROUND ZARIA

LOCALITY NO.	3	5	6	12
SAMPLE NO.	MD/3C/78	MD/5C/78	MD/6/78	MD/12/78
ROCK TYPE	PEGMATITE	PEGMATITE	PEGMATITE	PEGMATITE
% OF QUARTZ	21.74	18.18	28.57	25
% OF K-FELDSPAR	46.74	63.63	40	55
% OF PLAGIOCLASE	23.90	13.64	14.28	13.9
% OF BIOTITE	7.61	4.54	-	2.4
% OF TOURMALINE	-	-	17.14	-
TOTAL	99.99	99.99	99.99	99.99

Quartz:- Is the second most abundant mineral in Zaria pegmatites. They occur in anhedral crystalline aggregates and are generally glassy in colour. Grain size range from 2mm to about 2 cm across in the central core of some zoned pegmatites. They occur as intergrowth between other minerals like k- feldspar and as intragrowth within the tourmaline crystals (see plate 9).

Tourmaline:- Euhedral crystalline aggregates of black tourmaline or schorl is common in some pegmatites where well developed crystals occupy the central core of zoned pegmatites (see plates 6 and 7). They often contain intragrowth or infilling of quartz within cracks in their crystals (see plate 4).

Muscovite:- Thin books of muscovite do occur in some of the pegmatites. They are less conspicuous and generally less than 1cm in length.

3.2-4 Classification

According to Jahns (1955) pegmatites can be viewed as holocrystalline rocks that are at least in part very coarse grained, whose major constitution include minerals typically found in ordinary igneous rocks and in which textural variation in grain size is characteristic. From this broad definition, pegmatites can be divided like all Igneous rocks on

the basis of silica content as

i) Basic pegmatites

ii) Intermediate pegmatites

iii) Acid or granite pegmatites

The pegmatites under study belong to the last group i.e. acid or granite pegmatites, and they can be further sub-divided into simple and complex pegmatites on the basis of their mineralogy.

Landes (1933), defined simple pegmatites as those having undergone no hydrothermal replacement and complex pegmatites as those containing rare minerals introduced by late-stage hydrothermal fluids. But these definitions no longer hold. These terms have been re-defined, i.e. simple pegmatites have simple mineralogy and no well-developed zoning; complex pegmatites have an assemblage of rare minerals arranged in a zonal sequence (Park and Mac Diarmid 1964).

Mineralogically, there are two types of pegmatites in SW Zaria, these are:

Biotite bearing pegmatites and tourmaline bearing pegmatites apart from a pegmatite vinlet in loc. 10ii that contains both tourmaline and biotite, there seems to be no other pegmatite containing tourmaline and biotite.

The biotite bearing pegmatites are the commonest in SW Zaria and they are widely distributed. They have simple mineralogy consisting of k - feldspar, quartz, plagioclase and biotite and zoning is uncommon among them, although few of them are zoned. On the basis of the definition stated above, these pegmatites are considered in this report to be simple pegmatites.

The tourmaline bearing pegmatites exhibit distinct zoning with euhedral crystals of tourmaline in the central core. All the tourmaline bearing pegmatites except the one mentioned above do not contain biotite. They occur in both microgranite dykes (see plate 6) and porphyritic biotite granite (see plate 7). They are considered to be complex pegmatites in accordance with the definition stated above on the basis of their characteristic zoning and presence of tourmaline.

It is difficult to ascertain that the tourmaline bearing pegmatites are restricted to any part of the project area because they occur in the same outcrop with biotite bearing pegmatites i.e. (loc. 6 and 4), and in some localities i.e. locality I there exist only tourmaline bearing pegmatites.

3.2-5 Comments on the Origin of the Pegmatites

The origin of the pegmatites have been variously considered by previous workers as either due to metamorphic or Igneous processes.

Jacobson and Webbs (1935) in their theory of pegmatite formation mainteined that the natural history of the Nigerian complex pegmatites involves continuous differentiation by fractional crystallization of pegmatitic magma. On the other hand, McCurry (1970) suggested an in - situ metasomatic origin for pegmatites and aplites and went further to explain that recrystallization under differential shearing stresses produced the aplites while pegmatites formed during an episode of syn-kinematic to post-kinematic recrystallization and feldspathisation.

From the previous sections, it was shown that the pegmatites are confined to the areas of granitic intrusions, they maintain sharp contact with the host rock and have a regular trend (see fig. 3.1b and plates 3 and 6). If they had been metamorphic pegmatites, such features like irregular trends and gradational contact would have been observed. Zoning which is characteristic of the tourmaline pegmatites and some few biotite pegmatites have been explained and three hypotheses proposed are:

i) That zonal structure is formed by fractional crystallization in place under disequilibrium conditions.

ii) That progressively changing solutions deposit minerals along the walls of open channel. This hypothesis does not depend upon crystal fractionation and conditions of disequilibrium.

iii) That complex pegmatites are developed in two stages, namely: by the formation of a simple pegmatite by the direct crystallization of a pegmatitic fluid and by the partial or complete replacement of the simple pegmatite as hydrothermal solution pass through it. Most workers agrees with either the first or third hypothesis (Park and MacDiarmid 1958) and these hypotheses suggest magmatic origin for the pegmatites to produce zoning.

On the cross-cutting relationship between a tourmaline pegmatite and biotite pegmatite which indicates that the latter is older than the former, according to Bateman (1958), similar observations have been made by "many geologist who have studied the complex pegmatites and believe that the unusual minerals (tourmaline in this case) were deposited during one or more phases of hydrothermal replacement following the original formation of a simple quartz - feldspar mica pegmatite".

Similarly, on the observed field relationship between pegmatites and microgranite dykes, Jahns and Burham (1957) in their experiment designed to duplicate the conditions of pegmatites formation showed that pegmatites represent a residual melt of a fractionally crystallized magma in which two phases were present while crystals formed. They (Jahns and Burham) also made two major conclusions that:

a) Pegmatites and aplites may form completely independent dykes, depending on volatile content and pressure-temp. relation at various stages of cooling history.

b) Boiling may occur irregularly during cooling so that pegmatites and aplites form immediately adjacent to one another.

From the above, it is quite evident that the pegmatites in S.E. Zaria are most likely to be of magmatic origin and a probable mechanism of their formation can be reconstructed as follows:

That the fractional crystallization of granitic magma that formed the prophyritic biotite granite produced a residual fluid made up essentially of volatile, plus constituents of alkali feldspar together with other rare elements (particularly boron in this case) under high pressure and varying temperature conditions formed aplites leaving a more water

rich pegmatitic magma with higher concentration of volatiles. The subsequent fractures developed in the cooling granite causes sudden reduction in pressure and the emplacement of mica - rich pegmatites, while more phases of hydrothermal replacement with fractional crystallization in place under disequilibrium condition produced both the zonal structure and the complex or tourmaline bearing pegmatites.

3.3 Quartz Veins

3.3-1 Distribution

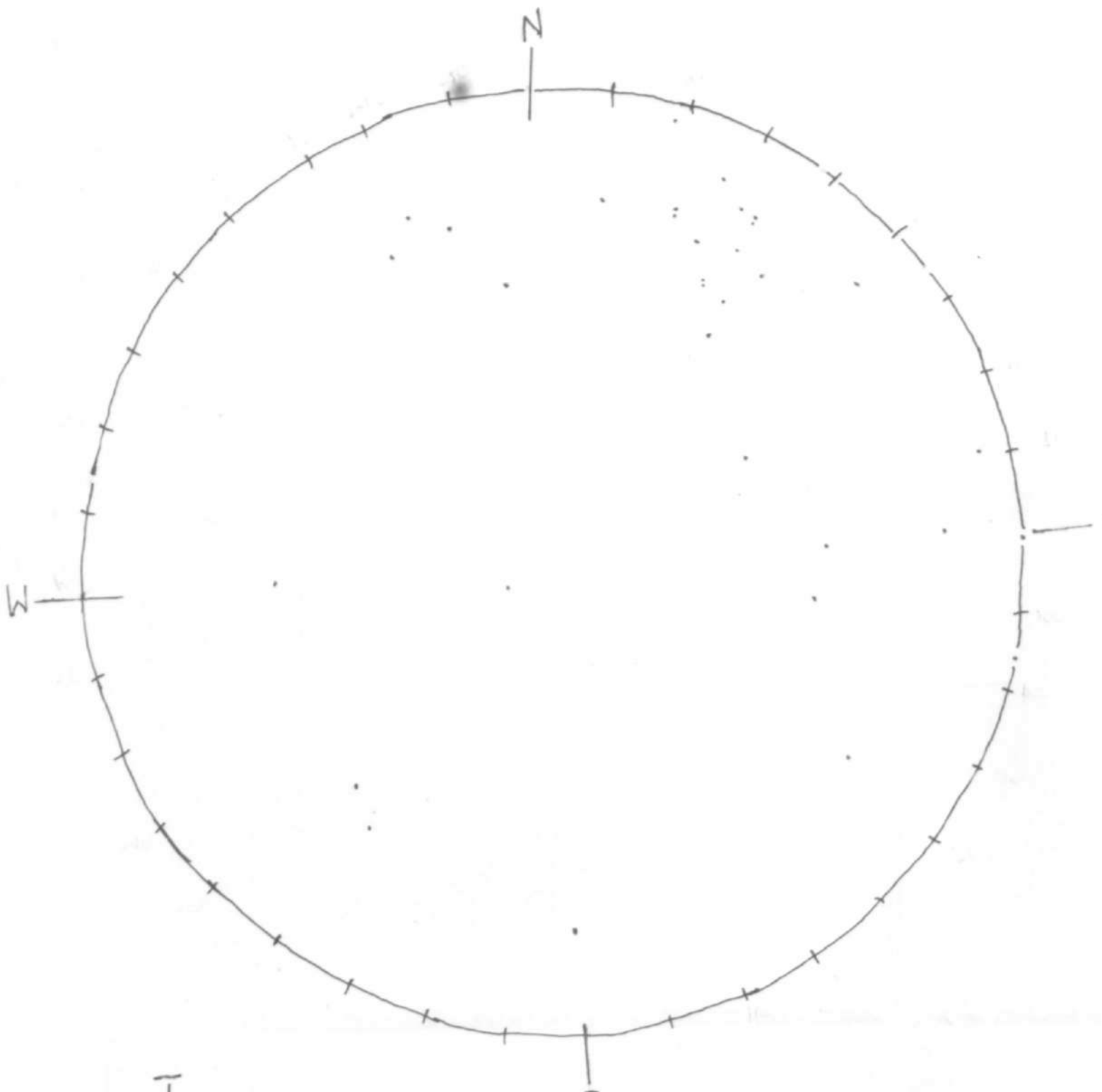
The distribution of quartz veins is treated under three paragraphs which are: spatial distribution on map; structural trend as shown by rosette diagram and the plot of poles to the fractures planes infilled by quartz veins.

Quartz veins exist in all the localities visited (see fig. 2.1) and the number of the veins found in each locality (see table 1) indicates that they are widely distributed. The total number of quartz veins observed is one hundred and fifty four, this is an average density of 3 quartz veins per km^2.

The general structural orientation of quartz veins can be seen at a glance on the rosette diagrams (Fig. 3.1c).

Fig. 3.7

PLOT OF POLE TO FRACTURE PLANES INFILLED BY QUARTZ



Total no. of pole plots = 32

One strike/dip reading is represented by a point.

There are three major trends viz: NW - SE (300°-310°), ENE -WSW (070°-090°) and N - S (000°-010°) in decreasing order of prominence. The NW - SE and ENE - WSW trending quartz veins are the commonest and they cut through the pre-existing microgranite dykes and pegmatites sometimes displacing them (see plates 8 and 9).

The plot of poles to the fracture planes infilled by quartz veins (fig.37) indicates concentration of pole plots within the N.E. quandrant and far away from the centre of the net. This clearly implies that the major trend is in N.W. - S.E. and the quartz veins are mostly dipping at high angle towards the S.W. direction. Although the number of pole plots are very few, they still provide an insight to the behaviour of the veins in depth.

3.3-2 Quartz Vein Types and Field Relationship

There are basically two types of quartz veins observed in the field, these are glassy and amethystine quartz veins.

Glassy Quartz Veins:- These are the commonest quartz veins in the project area. They are colourless or glassy and occur in the form of tiny veins and thin attenuated slabs along fault planes in porphyritic biotite granite and often in microgranite dykes. They are generally small in size (see appendix 4) maximum thickness is about 10cm. They are

usually very short and discontinuous although a particular vein was traced for more than 30 meters in Kufena granite. The quartz veins are particularly confined to the porphyritic biotite granite intrusions and are mostly discordant to its foliation. In all the localities except loc. 14, there occurs tiny quartz veins cutting through the pre-existing microgranite dykes and pegmatites (see plates 8 and 9). The observed cross-cutting relationship suggests that the quartz veins are younger than the other minor formations.

Amethystine Quartz Vein: Purple coloured amethystine quartz veins occur in laterite about 2 km. south of Kufena hill loc. 14. The veins contain small lenses of highly brecciated amethyst grains in an annealed siliceous cement. The brecciation according to McCurry (1970) must have been due to the fact that the veins occupied a fracture plain that is related to the regional joint pattern. The host rock of the amethystine quartz veins is a decomposed granite that has been lateritized. Despite the lateritization, the amethystine quartz veins appeared to have retained its original structural trend.

3.3-3 Comments on Origin of Quartz Veins

Quartz veins in South-West Zaria like all the other minor formations are confined to areas of granitic intrusions where they have a general NW - SE and ENE trends. Their sharp contact relationship with the host rock and siliceous nature tend to suggest that they formed from a highly siliceous aqueous residuum of a fractionally crystallizing magma, that was emplaced, cooled and solidified in a NW - SE and ENE trending fractures in the porphyritic biotite granite. The strong attenuation of some of these veins also indicate that at the time of their emplacement, minor displacements occurred in the host rock along the fracture planes before complete solidification of the siliceous material. The amethystine quartz vein could be products of the same siliceous magma that was contaminated at the time of emplacement.

By correlating these facts with that of the other minor formations, there appear to be a trend of magmatic activity punctuated by the emplacement of microgranites, pegmatites and the last siliceous residuum formed the quartz veins. Therefore, the quartz veins of S.W. Zaria must have been formed from the same magma that produced the pegmatites and microgranites, in which case they are also of magmatic origin.

CHAPTER FOUR

STRUCTURE AND PROPOSED MODE OF EMPLACEMENT OF THE MINOR FORMATIONS

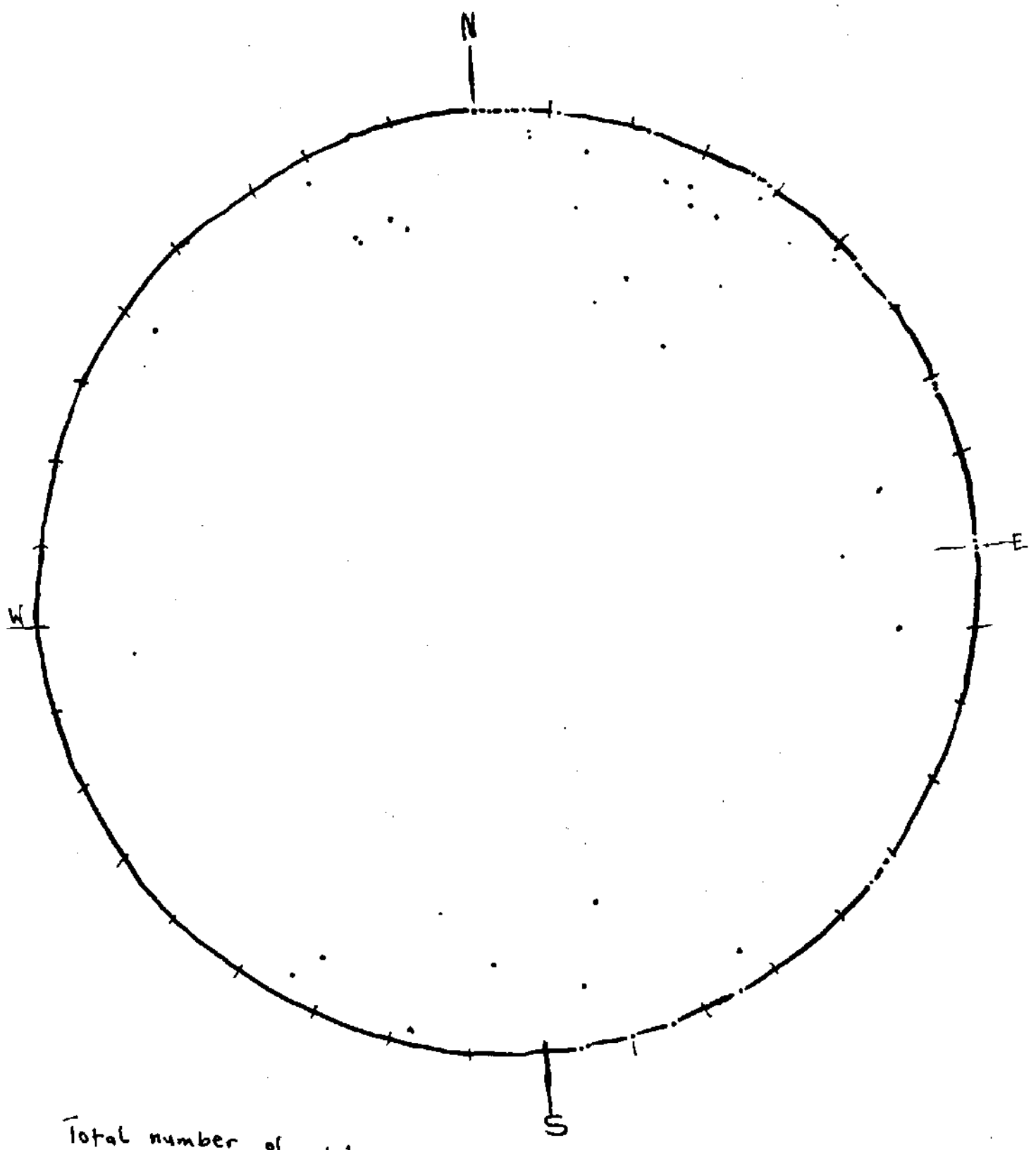
4.1 Structural Relationships

The major structural trend that will be discussed here are the joints i.e. both gaping and the ones infilled by the minor formations.

Gaping joints are very common in SW Zaria particularly in the porphyritic biotite granite outcrops (see plate 11). They are mostly very short, the maximum length observed in the field is about 20 meters loc. 6 and most others are not longer than 5m. They cut across the pre-existing microgranites, pegmatites and are mostly discordant to the foliation of the porphyritic biotite granite. The number of joints located in each locality vary (see table 1), however, one hundred and fifty four gaping joints were located in this study.

Fig. 3.1d is a rosette diagram of the gaping joints from which three major trends are notable viz: 290°-320°, 070°-090° and 350°-010° corresponding to NW, ENE and N - S trends respectively. It shows that most of the gaping joints around Zaria are trending NW, ENE and N-S and it agrees with field observation that most of the joints cut across the pre-existing minor formations.

Fig. 4.1 Plot Of Poles To Gaping Joints Around Zaria



Total number of pole plots = 55

One strike/dip reading is represented by a point.

The plot of poles to the planes of gaping fractures/ joints around Baria (fig.4.1) also indicate concentration of pole plots to the NE quandrant and far from the centre of the net. It means that most of the gaping joints/fractures are trending NW - SE and dipping at high angles South-Westwards. This is actually what was observed in the field.

A close look at the rosette diagrams (fig.3.1) of the minor formations and gaping joints also revealed that

i) NNW and NNE trends are common to all the minor formations and the gaping joints, but they are more prominent in microgranites and pegmatites.

ii) NW-SE and ENE trends are not common or prominent in microgranites and pegmatites, but are relatively the major trends of quartz veins and gaping joints.

From the previous sections, it was shown that the microgranites are the oldest followed by pegmatites which are in turn older than the quartz veins. Therefore the NNW and NNE trending joints are likely to be the oldest joints formed in the porphyritic biotite granite and were infilled by microgranites, pegmatites and quartz veins, the remnants are still recorded as gaping joints. While the NW and ENE trending joints which are mostly either infilled by quartz veins or left as gaping joints are most probably younger than the NNE

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and NNW trending joints. The fact that in almost all the localities quartz veins and gaping joints cutting across the pegmatites and microgranites were recorded, also confirm this idea.

The major interpretation therefore is that there were most probably at least two jointing episodes in the Zaria porphyritic biotite granite.

4.2 Sequence of Events

Porphyritic biotite granites are a part of the Nigerian older granite which was intruded during the Pan - African Orogeny of late proterozoic to early paleozoic age into both the crystalline basement complex and the meta-sedimentary belts and with this are associated several phases of aplite and pegmatite emplacement, McCurry (1970).

Based essentially on field observations, this author is of the opinion that after the emplacement of the porphyritic biotite granite, the roof of the intrusion started first to solidify while the inner part of it was still essentially molten. This molten material remain under high pressure condition without formation of aqueous phase. The East-West tensional stresses due to Pan-African Orogeny produced high angle Westward dipping, North - South trending joints in the porphyritic biotite granite which tapped the

molten material in the intrusive porphyritic biotite granite, that cooled rapidly and formed the aplitic or sugary textured microgranites which are also essentially granitic in composition.

After the emplacement of microgranites, the residual fluid which was made up essentially of volatiles plus rare elements like boron, (and probably lithium, cesium which are not commonly accommodated in rock forming silicate structures) and water similarly rose through the joints in the cooling rock (and some already infilled by microgranites) as a result of sudden pressure reduction and mica rich pegmatites were emplaced, while resurgent or more phases of hydrothermal replacement with fractional crystallization in place under disequilibrium condition produced both the zonal structure and the complex or tourmaline bearing pegmatites.

Further to the emplacement of pegmatite, the remaining fluid was essentially siliceous and these were emplaced in the joints developed in the porphyritic biotite granite to form quartz veins.

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Further to the emplacement of pegmatite, the remaining fluid was essentially siliceous and these were emplaced in the joints developed in the porphyritic biotite granite to form quartz veins.

TABLE 4 - COST AND USES OF ZARIA GRANITES

SERIAL NO.	SIZE AFTER CRUSHING	PRICE PER LORRY LOAD 3.8cu.m 5cu.yd	USES AND CONSUMERS
1	Lumpstone	30 - 40 lump ₦30.00	Used for building
2	2" - 3" lumps	₦30.00	Building culverts and concrete works in general. Railway balasts
3	1½" - ¾" lumps	₦60 - ₦70.00 (₦65.00)	
4	¾" - 3/8" lumps	₦120 - ₦150.00 (₦135.00)	Building and road metals
5	C 3/8" stone dust	₦30.00	Concrete industry for blocks

(After J.A. Olatunji (In Preparation))

CHAPTER FIVE

ASPECT OF ECONOMIC GEOLOGY

Discussion on the economic importance of the rocks mentioned in this report is based on their present economic value and their anticipated economic importance.

Presently, the most economically important rock in the project area is the porphyritic biotite granite. Quarrying activity of the granite by building contractors provides employment for an estimated labour force of about 1,400 people (Dr. J.A. Olatunji, personal communication). Majority of these people are involved in rock blasting and crushing using principally explosives which causes major cracks and blasting of large chunks of rock which are then broken into various sizes and gathered into large heaps for onward transportion by lorry to the consumers. The consumers of the various sizes differ and the cost of lorry load of each rock size as well. A table of the cost per lorry load of each rock size and the uses is attached herewith (see table 4).

In order to appreciate the profit being made from this business which involves private business men and the government, below is a review of monetary worth of an outcrop.

A single outcrop i.e. Hanwa outcrop loc. 3 (see fig. 1.1) cover an estimated area of about 10,000 m^2 and its height

above the general terrain is about 20m. Therefore the volume of rock that can be quarried conviniently above the general terrain = 200,000 m^3

The volume of a lorry load of rock = 5 m^3

∴ the total number of lorry loads that can be obtained from this single outcrop = $\frac{200,000\ m^3}{5\ m^3}$

= 40,000 lorry loads.

From the table, assuming an average cost of ₦50 per lorry load of rock, irrespective of rock size, then the total worth of the exposed rock = 40,000 x ₦50

= ₦2,000,000

There are more than 20 outcrops of porphyritic biotite granite around Zaria of different sizes, therefore, it may not be out of place to say that this business is really a lucrative one. The expenses on this business can be in the form of wages for the labourers, tax, cost of instruments, licences and possibly insurance cost. Since the rocks are exposed, there is no need to pay consultancy fee for their location.

It is therefore not surprising that nearly every outcrop around Zaria is now being quarried and in fact, it provides an opportunity to obtain fresh samples. The simple fact that this business is increasing daily means that the people

involved are making a lot of profit out of it. Basically, the rocks are being used for building, road work, dams and rail ballast.

Laterite:- Is another economic raw material which is used mainly for road surfacing and building of local houses.

Minerals -

Amethyst:- Occurs in veins about 2 km. South of Kufena. Although it is brecciated and colour variations exist in it, it could still be of semi-precious quality. Particularly in making ornaments, Jewellery and for decorative purposes.

Feldspars:- Is the most abundant mineral here both in the granite and the pegmatites. Although it plays a minor role in industry as a component of glazes or pottery, their weathering product are of primary importance in ceramics and agriculture.

Tourmaline:- Black iron bearing tourmaline exist here in some of the pegmatites. It could be a major source of boron and for services in such articles of jewellery as pendant ear-rings and brooches.

Apart from the potentials in quarrying economically, the pegmatites in this region could yield major economic minerals. Pegmatites have been variously considered by many geologists as sources of materials for detailed meneralogic

investigation, because it serves as host rocks for many economically valuable deposits.

In fact, pegmatites according to Park and MacDiarmid (1964) are the only sources of some metals. They contain tantalum, niobium, beryllium, cesium, Uranium, cerium, lanthanum, thorium, Ytlrium, and many other rare elements in a host of uncommon and complex minerals as well as the better known collectors items such as topaz, garnet, spodumene, monazite, tourmaline (which occurs in the pegmatites here), cassiterite, tantalite, columbite, beryl and lepidolite.

In Nigeria, 98% of the cassiterite produced is mined in younger granite masses in Jos Plateau, Bauchi, Zaria, Kano and Benue provinces. Some amount are also won in granite pegmatites in the former Plateau, Kabba, Benue, Niger and Ondo provinces (Kogbe and Obialo 1976). The Uluguru mica pegmatites of former Tangayika apart from mica yields sphalerite, Talc, Uranium, Arsenopyrite, Apatite, Beryl, Rutile etc. Similarly pegmatites of Petaca district in New Mexico that lies within precambrian rocks of San Juan nountains according to Jahns (1946) contain significant concentration of the following minerals, Beryllium, Columbium, tantelum, bismuth, Uranium, thorium and the rare-earth metals. The economic importance of these minerals listed

above that exist in pegmatites are too well known to be recalled here. The fact that pegmatites in Zaria appears barren at the present erosional level does not mean that it contains no economic mineral deposit down below. In fact, Jahn (1946) explained that pegmatites that appear barren at the surface might be very complex with distinct zoning and concentration of economic minerals deep down. It is therefore the opinion of this author that there might be very valuable economic minerals in these pegmatites deep down.

CHAPTER SIX

DISCUSSION AND CONCLUDING REMARKS

6.1 Discussion

On the origin of the Minor Dyke-Like bodies

In Chapter three, the available field evidences were used to establish for each minor formation a possible magmatic origin. But, McCurry (1970) suggested that microgranites were produced by recrystallization under differential shearing stresses while pegmatites formed during an episode of syn-kinematic to post-kinematic recrystallization and feldspathisation. In other words, McCurry felt that the pegmatites and microgranites have metamorphic origin.

In order for this assertion to be true, the said recrystallization under differential stresses that produced the microgranites must have occurred before an episode of syn-kinematic to post-kinematic recrystallization and feldspathisation that formed the pegmatites since the cross-cutting relationship between the pegmatites and microgranites suggests that the latter is older than the former. The observed concordance and often slight discordance of the pegmatites and microgranites to the general lineation of k-feldspar in the porphyritic biotite granite tend also to support this view.

However, the other major field evidences like regular trends of the minor formations and their sharp contact relationship with the porphyritic biotite granite instead of irregular trends and diffused or gradational contact suggest a magmatic rather than a metamorphic origin. Similarly the presence of porphyritic biotite granite xenolith in the microgranite dykes and pegmatites physically suggest that the pegmatites and microgranites were intruded into the porphyritic granite. The intimate association between microgranites and pegmatites, their compositional similarities with host granite favour the view expressed by Jahns and Burham (1957) that pegmatites and aplites may form completely independent dykes depending on volatiles contents and pressure-temperature relations at various stages of cooling history or boiling may occur irregularly during cooling so that pegmatites and aplites may form immediately adjacent to one another. In which case they are products of the same fractionally crystallized magma and are thus of magmatic origin.

The age relationship between the minor formations based on their cross-cutting relationship i.e. the microgranites are older than the pegmatites which are in turn older than the quartz veins, is more in conformity with the expected

trend of a fractionally crystallized magma which tends to be progressively siliceous and marked by the emplacement of microgranites, pegmatites and lastly quartz. Therefore it is obvious from the foregoing that the minor formations are genetically related and most unlikely to be of metamorphic origin.

6.2 Concluding Remarks

6.2-1 Conclusion

The field study of the minor dyke-like bodies in S.W. Zaria revealed that there exist cross-cutting relationship among the microgranites (fig.5) and among the pegmatites. These relationships suggest that there occurred several phases of microgranites and pegmatites emplacement in the porphyritic biotite granite. Also on the basis of cross-cutting relationships among the minor formations, it was established that the microgranites are the oldest followed by the pegmatites which are in turn older than quartz veins. Considering the predominance of NNW and NNE trends of microgranites and pegmatites, the NW and ENE trends of quartz veins and the gaping joints, and the cross-cutting relationships between the former and the latter, there must have been at least two fracturing episodes in the porphyritic biotite granite.

Although the origin of the porphyritic biotite granite is still controversial as McCurry (1970) proposed that the feldspar megacryst grey by porphyroblastesis while Kayode (1976) suggested that the feldspar megacrysts in both variants of the Igbo-Ora porphyritic older granite were formed by phenocrystic crystallization from melt, this author have tried to establish a genetic relationship between the minor formations and the porphyritic biotite granite based on their mineralogical similarites and close association.

On the basis of this genetic relationship, if the magmatic origin proposed for the minor formations is acceptable, then the conclusion of this report is that the porphyritic biotite granite is most likely to be of magmatic origin.

6.2-2 Recommendation for further work

In order to get more reliable information on the origin of the porphyritic biotite granite, it is recommended that further investigation be carried out on certain dark coloured xenoliths that exist in the rock and the causes of their allignment. As Kayode (1976) pointed out in his paper on Igbo-Ora complex, S.W. Nigeria, that in order to give satisfactory explanation to the origin of the porphyritic biotite granite, this author feels strongly that the origin of the feldspar megacrysts could provide the solution to the origin of the porphyritic biotite granite.

This is better done by electron microprobe analyses which will reveal the trace element ratio in the phenocryst and the groundmass and from which one can infer whether the feldspar megacrysts formed by metasomatism or by crystallization from melt. The nature of the contact of the porphyritic biotite granite and the biotite gneiss should also be investigated.

Further investigation of the complexity of Zaria pegmatites and indeed the other minor formations like that of Olatunji (in preparation) is also necessary.

Since pegmatites are so widely distributed in this area and there are evidences that they contain rare mineral like tourmaline, it is possible that at lower erosional level there are more economically important minerals like Uranium, thorium, beryl, cassiterite etc. It is therefore recommended that further investigation be carried out on the pegmatites.

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APPENDIX 1 LIST AND DESCRIPTION OF SAMPLES

SAMPLE NO.	DESCRIPTION OF LOCALITY	MAP SHEET NUMBER	NAME AND DESCRIPTION OF ROCK SAMPLE	GEOLOGICAL SETTINGS	STAINED	REMARKS
MD/1a/78	11°9.2'N 7°38.2'E BZ Outcrop	Zaria 102 SW	Tourmaline bearing pegmatite in contact with microgranite dyke with coarse grained and euhedral tourmaline crystals	Tourmaline pegmatite in a microgranite dyke found in situ		
MD/1b/78	-do-	-do-	Tourmaline bearing pegmatite's central core with predominant tourmaline and quartz	Zoned tourmaline bearing pegmatite found in microgranite		
MD/2a/78	11°8.4'N 7°41.2'E Kano junction outcrop	"	Porphyritic biotite granite with large microcline megacryst embedded in a matrix of biotite	Large whale back found in situ.		
MD/2b/78	-do-	"	A fine grained microgranite with sugary texture as light grey in colour	A big dyke in the country rock which is porphyritic biotite granite		
MD/2c/78	"	"	A coarse grained biotite pegmatite with large crystals of quartz in the central core	Zoned biotite pegmatite found in porphyritic biotite granite.		
MD/2d/78	"	"	Thin slab of quartz that is sheared or stretched and glassy in colour	Sheared quartz vein in porphyritic biotite granite		
MD/3a/78	11°07'N, 7°42.8'E Hanwa outcrop near Primary School	"	Shiny black coloured amphibolite that is fine-grained	Xenolith in country rock		

Appendix 1 - contd.

(3)

SAMPLE NO.	DESCRIPTION OF LOCALITY	MAP SHEET	NAME AND DESCRIPTION OF ROCK SAMPLE	GEOLOGICAL SETTINGS	STAINED	REMARKS
MD/6/78	11°8.9'N,7°42.6'E Outcrop near Ungwan Abarshi	Zaria 102 SW	Coarse grained tourmaline bearing pegmatite in country rock with well developed crystals of tourmaline	Tourmaline pegmatite in country rock found in situ	✓	
MD/8a/78	11°05.5'N - 7°43.73'E Kongo Outcrop	-do-	Fine grained microgranite, light grey in colour with sugary texture	Microgranite dyke in the country rock "in situ"		
MD/8b/78	-do-	"	Coarse grained pink coloured pegmatite containing biotite	Pegmatite in country rock found in situ		
MD100/78	11°03.3'N - 7°43-25'E Zaria City Outcrop	"	Coarse grained pink coloured biotite pegmatite.	Pegmatite in country rock found in situ.		
MD/110/78	11°05.3'N,7°41.5'E Tukur-Tukur outcrop behind Barewa College	"	Coarse grained biotite pegmatite	Pegmatite in country rock found in situ.		
MD/12/78	11°05'N,7°39.5E Kufena hill	"	Coarse grained biotite pegmatite	Pegmatite in country rock found in situ	✓	
MD/13a/78	11°4.5'N,7°40.5'E	"	Coarse grained biotite pegmatite	Pegmatite dyke in country rock found in situ		
MD/13b/78	-do-	"	Glassy quartz lump containing crystalline aggregate of quartz	Quartz vein in country rock		
MD/14/78	11°03.8'N, 7°40.5'E	"	Rose/pink coloured brecciated anethyrtine quartz	Anethyst vein in laterite found in situ		

Appendix 1 - contd.

SAMPLE NO.	DESCRIPTION OF LOCALITY	MAP SHEET NUMBER	NAME AND DESCRIPTION OF ROCK SAMPLE	GEOLOGICAL SETTINGS	STAINED	REMARKS
MD/3b/78	11°07'N, 7°42.8'E Mamwa Outcrop near Primary School	Zaria 102 SW	Fine grained microgranite in contact with porphyriblastic biotite granite	Microgranite dyke in the porphyritic biotite granite found "in situ"		
MD/3c/78	--do--	--do-	Coarse grained biotite pegmatite with pink colour	Pegmatite in the porphyritic biotite granite found in situ	✓	
MD/3d/78	"	"	Coarse grained pink coloured pegmatite (smaller grain size than 3c)	Pegmatite in the country rock not in situ.		
MD/5a/78	11°7.1'N, 7°40.5'E Outcrop near Unguan Mallam Tsofo near Zango	"	Porphyritic biotite granite with megacrysts microcline embedded in a finer matrix	Exposed in a river channel		
MD/5b/78	--do--	"	Fine grained microgranite with sugary texture and light grey in colour	A dyke in the country rock.	✓	
MD/5c/78	"	"	Coarse grained pegmatite with interlocking quartz crystals and microline	Pegmatite in country found in situ		
MD/5d/78	"	"	Glassy coloured quartz	Quartz vein in country rock		

APPENDIX 2 - ATTITUDE AND WIDTH OF MICROGRANITE DYKES AROUND ZARIA

Strike/Dip	Width	Strike/Dip	Width	Strike/Dip	Width
000/62W	1.5m	000/90	70cm	010/50W	6m
348/60NE	1m	010	40cm	057/67SE	4m
000/90	2.3m	333	3m	336/49W	5m
168	1.5m	166	3.2m	351	3m
035	10m	332	2m	330	40cm
030/I	3.5m	340	3m	000/70W	50cm
016/58NE	80cm	340	2m	330	20cm
000/59NW	40cm	332	4m	140	20cm
008/90	3m	013	60cm	020/60E	5m
000/90	11m	024/53E	2.5m	160/70W	4.5m
352/90	1.2m	159/55W	15cm	000	30cm
338/53SW	20cm	153	10cm	162	15cm
352/69W	1.5m	040	1m	004	6cm
006/48W	50cm	030/39NW	40cm	345/23SW	30cm
003/66w	40cm	028/30/NW	40cm	327/53NE	5m
019/55w	20cm	126	40cm	345	4m
346	40cm	160/20W	1m	000/77W	13cm
358	1.5m	013/41W	40cm	002	40cm
000	3m	349/72NE	10cm	176/31W	50cm
002/90	2.5m	332/57NE	16cm	004/61W	50cm
011	50cm	310/15NE	70cm	178/43W	3.5m
003/90	80cm	342	70cm	035/55NW	70cm

Appendix 2 Contd.

Strike/Dip	Width	Strike/Dip	Width
001	80cm	329	40cm
048/32NW	20cm	170/46W	11cm
000	2m	174/71E	15cm
356/78W	1m	011	50cm
354/73W	22cm	346	5m
350	10cm	350	80cm
347/73W	1m	156/65NE	6cm
342	70cm	014	6cm
017	1.2m	152/78SW	1.5m
352	1.0m	193/63W	15cm
345	8cm	344/41W	45cm
000/59E	2m	350	2m
037	85cm	000/66W	30cm
006	15cm	352/55W	65cm

APPENDIX 3 - ATTITUDE AND WIDTH OF PEGMATITES AROUND ZARIA

Strike/Dip	Width	Zoning	Strike/Dip	Width	Zoning	Strike/Dip	Width	Zoning
147	16cm		355/90	10cm		340/65W	4cm	
018/62NW	10cm		112/90	30cm		343/90	6cm	
032/62NW	11cm		160/73W	40cm		003/-		
000/43NW	18cm		040	25cm	/	350/-		
172	1.0m		340/84SW	10cm	/	354/-		
172	45cm		345	5cm		160/60SW		
149/47NE	42cm		338/53SW	5cm		180/90		
061/23NW	30cm		342/64SW	7cm		124	25cm	/
010/90	35cm		344	5cm		154		
016/57NW	1.3m		346	22cm		258	5cm	
136/70NE	3.5cm		340	20cm		147	20cm	
164/90	22cm		176/70E	22cm		154	65cm	
003/52W	30cm		340/90	20cm		258	30cm	
001/47W	25cm		326	5cm		147	30cm	
004/48W	40cm		330	40cm		154/90	25cm	
044/57NW	25cm		340	10cm		038/90	40cm	
267/78S	15cm		018	35cm		324	10cm	/
203/57NW	20cm		334	12cm		320	10	/
098/90	50cm	/	340/65W	30cm		316	10cm	
345/90	15cm		343/90	3cm		294/90	30cm	

Appendix 3 - contd.

Strike/Dip	Width	Zoning	Strike/Dip	Width	Zoning	Strike/Dip	Width	Zoning
310	35cm		161	50cm		026	3cm	
230/58SE	60cm		167	70cm		176	30cm	
316	10cm		088/90	30cm	/	85/59N	20cm	
300	10cm	/	016/73NW	15cm		162/70SW	7cm	
348/81NE	4cm		177	5cm		000	2cm	
016/60E	35cm		033/90	2m	/	004/90	30cm	
210/49E	20cm		178	10cm		000	90cm	
140/82NE	40cm		015/67E	20cm		168	15cm	
020/70E	10cm		032/67SE	50cm		322	20cm	
004	40cm		030/55SE	65cm	/	354	3cm	
004	3m		004/69W	10cm		347	10cm	
242	11cm		320	5cm		105/38N	3cm	
018/55E	1.35m		028/64N	40cm		010/20E	2cm	
007/59SE	70cm		314	10cm		300/40SW	10cm	
039/59SE	30cm		246	15cm		342/31W	3cm	
018/43NW	40cm		168	7cm		356/45W	2cm	
022	1m		052/28NW	30cm		337/55SW	5cm	
030/39NW	15m		076	30cm		110	10cm	
014	40cm		292	4cm		011	65cm	
028/30NW	35cm	/	346	3cm		005/69W	5cm	
011/57NW	30cm	/	000	6cm		018	40cm	
004/60E	75cm	/	346	15cm		178/43W	65cm	

Appendix 3 - contd.

Strike/Dip	Width	Zoning	Strike/Dip	Width	Zoning	Strike/Dip	Width	Zoning
347	50cm		010	32cm		157	35cm	
174	50cm		006/51W	45cm		310	14cm	/
020	70cm		008	5cm		009	15cm	
016	15cm		032	5cm		282	10cm	
034	20cm		017	25cm		204	35cm	
000/61W	30cm		343/61SW	18cm		006	30cm	
191/65W	15cm		010	65cm		208	30m	
004	20cm		021	45cm		354	3cm	
354	10cm		010	18cm		000/56W	8cm	
010/64W	5cm		011	20cm		010	10cm	
350	40cm		012/65W	25cm		162/70E	10cm	
142/68SW	7cm		006/80E	30cm		320	1m	
000	5cm		003	50cm		357/69E	4cm	
313	10cm		013	15cm		000	10cm	
000	20cm		352	25cm		357	15cm	
006/49W	19cm		009	8cm		080	15cm	
			009	6cm				

APPENDIX 4 - ATTITUDE AND WIDTH OF QUARTZ VEINS AROUND ZARIA

Strike/Dip	Width	Strike/Dip	Width	Strike/Dip	Width	Strike/Dip	Width
135/55NE	6.5cm	012	5cm	262	2cm	088	2cm
129/60NE	5.5cm	024	7cm	249	4cm	095	2.5cm
128/90	7cm	00/50E	2cm	244	2cm	088	2.5cm
113/65S		019	3cm	243	2cm	289/85S	3cm
126	13cm	007	3cm	251	4cm	296	3cm
124/80SW	2cm	308/48SW	5cm	302/55W	3cm	291	3cm
146/90	6cm	111/90	3cm	326	4cm	273	4cm
124/65SW	4cm	091	1cm	176	3cm	281/65S	3cm
152/10NE	5cm	106	3cm	050	2cm	065/65SE	4cm
182/48W	3.5cm	089	1cm	176	3cm	078	3cm
110/90	2cm	085	1cm	044	2cm	121	1cm
014/46W	5cm	086	2cm	010	40cm	304	3cm
002/90	2cm	109	3cm	336/27W	40cm	305	2cm
310/90	1cm	126	4cm	350/82W	5.5cm	298	3cm
265	2cm	112	1cm	252	1cm	304	4cm
270/90	1cm	080	1cm	298/63SW	5cm	107	3
255/62S	2cm	251	3cm	267	5cm	293	2
325	3cm	090	3cm	256	5cm	326	5
320/90	3.5cm	240	2cm	270	4cm	352	10
293/66S	10cm	258	4cm	251	3cm	006	2
019	15cm	250	3cm	259	3cm	311	10
137	3cm	262	1cm	083/50S	2cm	314	10

Appendix 4 - contd.

Strike/Dip	Width	Strike/Dip	Width
133	5	118/76SW	2cm
015	3	312	2cm
327	5	271/69N	3cm
314	4	316	2cm
304	4	250/67S	3cm
002	3	302/71SW	3cm
127	2.5cm	132	4cm
304/72SW	1cm	049	3cm
310/64SW	4cm	308	1cm
305	3cm	300	2cm
321/76SW	5cm	016/90	15cm
039/64NW	6cm	00/72W	11cm

APPENDIX 5 - ATTITUDE OF GAPING JOINTS AROUND ZARIA

STRIKE/DIP	STRIKE/DIP	STRIKE/DIP	STRIKE/DIP	STRIKE/DIP
121/79NE	078/67S	092	110	329/83SW
123/85NE	106/87NE	314	110	311
040/82SE	067/83SE	097/88S	092/90	014
018	309/90	041/90	160/90	102
026	346	130	000	022
284	286	088	355	264/77N
284	320	000/90	000/90	018
134/82SW	266/90	000	140/88SW	273
085/90	001/68W	097	142/90	298
094/90	284	342	004	304
000	064/90	044/90	105	320
063/82NW	073	040	105	327
160/90	079/90	056	006	022
128/88SW	162	136	005	318
078/60N	076	082	355	324
148/90	076/90	120	323/90	058
114/90	160	010	174	303
104/80S	150	310	296/58S	050
070/67SE	353/80NE	317	277/70N	224
070/68SE	276	020	296	258
076/70SE	126/90	000	343	022

Appendix 5 - contd.

STRIKE/DIP	STRIKE/DIP	STRIKE/DIP	STRIKE/DIP
342	260	197	110
271	295	260	308
104/82S	317	130/65SW	121
103	043	304/72SW	000
107	282	291/50SW	298/80SW
280	106	176	170/70SW
101	290	296/80SW	190
263	281	300/77SW	117
262	313	291	019
053	290	286	016
016	116	000	012/73NW
	000	306	128/50SW



PLATE 1 - Cross-cutting relationship of younger pegmatite with an older microgranite dyke. Both are minor formations in the porphyritic older granite of Zaria
(from Loc. 10ii)
Pg - pegmatite, Mg - Microgranite
Pbg - porphyritic biotite granite



PLATE 2 - A younger biotite pegmatite in porphyritic biotite granite of Zaria
Pg - pegmatite, Pbg - porphyritic biotite granite
Note the sharp contact (from Loc. 11)



PLATE 3 - Structurally controlled younger pegmatite in a large microgranite dyke.
Pg - pegmatite, Mg - microgranite
(from Loc. 1).



PLATE 4 - Stained slab of tourmaline pegmatite in contact with microgranite.
Mg - microgranite, T - Tourmaline,
O - quartz Fsp - k-feldspar.
Note: quartz infillings in the tourmaline crystals
(from Loc. 1)

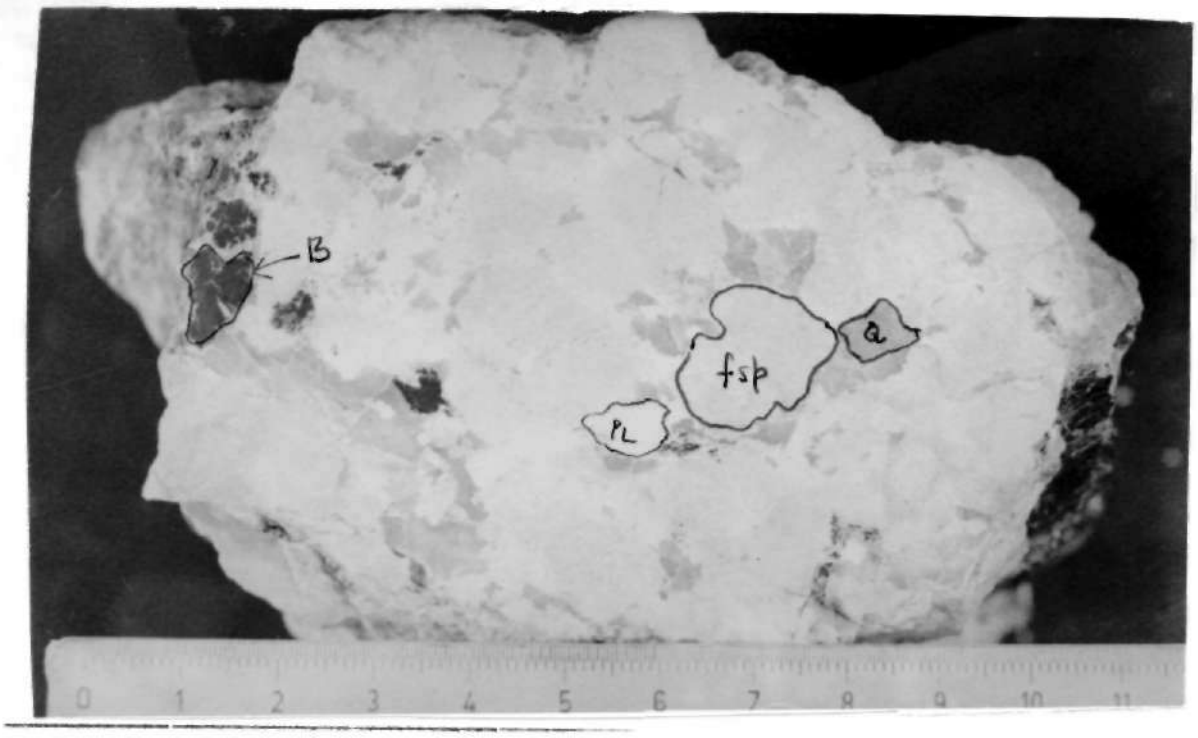


PLATE 5 - Stained slab of biotite pegmatite
B - biotite. Q - quartz, fsp - K-feldspar,
PL - plagioclase
(from Loc. 3)

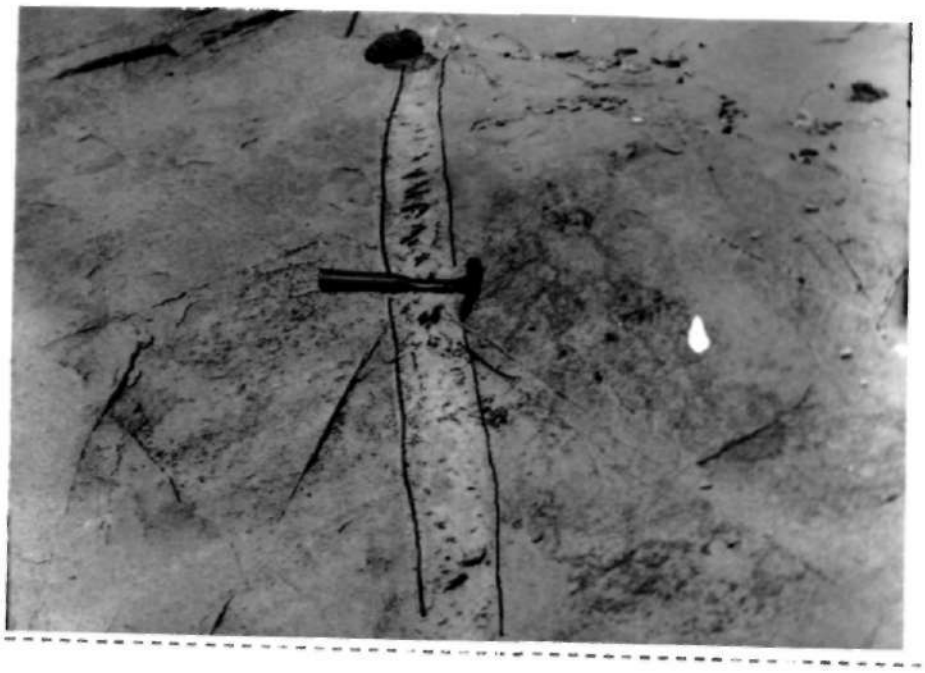


PLATE 6 - Example of a zoned tourmaline pegmatite in older microgranite dyke.
(from Loc. 1)

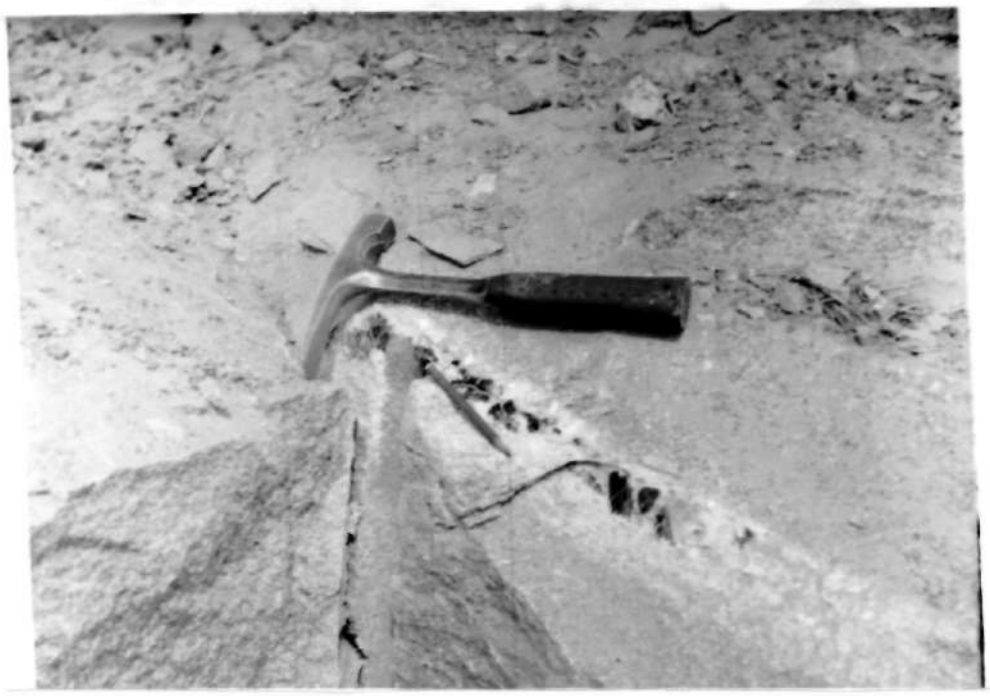


PLATE 7 - Example of a tourmaline pegmatite pod within Zaria porphyritic biotite granite.
(from Loc. 6)

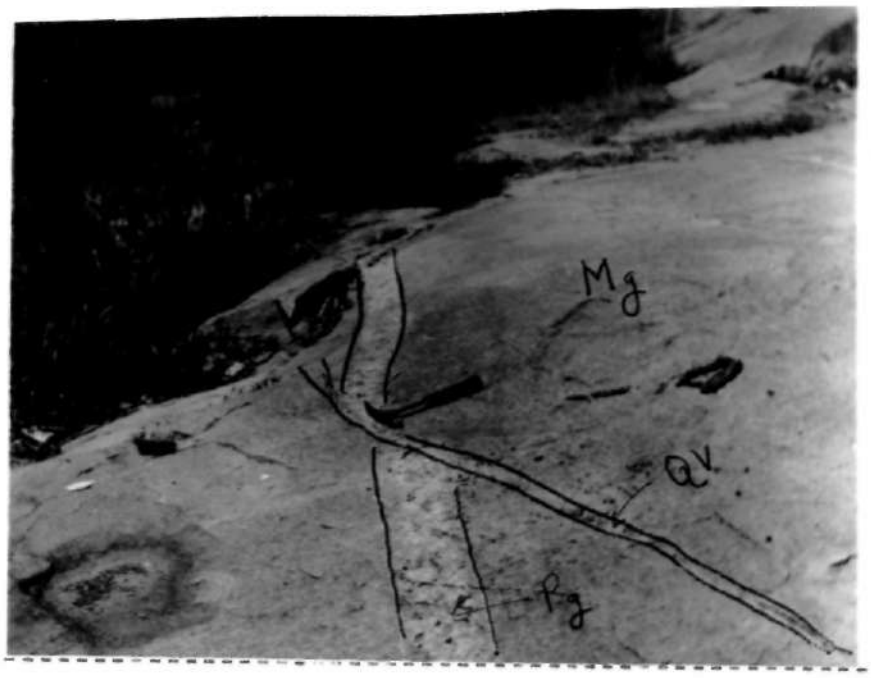


PLATE 8 - Cross-cutting relationship between an older pegmatite and quartz vein in a microgranite dyke.
Mg - microgranite, Pg - Pegmatite, Qv - quartz vein
(from Loc. 1)



PLATE 9 - Example of a younger quartz vein cutting an older micro-granite dyke.
(from Loc. 1)



PLATE 10 - Part of a younger quartz vein penetrating the porphyritic biotite granite of Zaria (Loc. 10ii). Note the sharp contact.
Qv - quartz vein, Pbg - porphyritic biotite granite.



PLATE 11 - Example of parallel jointing in Zaria porphyritic biotite granite (Loc. 7)



PLATE 12 - Example of parallel jointing in Zaria microgranite dykes.



PLATE 13 - A pegmatite modified by deformation after emplacement in the porphyritic biotite granite of Zaria (Loc. 2).