

# Field Features And Mode Of Emplacement Of Pegmatites Of Keffi Area, North Central Nigeria

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**Abstract:** The Keffi area of North Central Nigeria hosts numerous pegmatite bodies which are related to the surrounding granitic intrusions islocated about 45 km east of the Federal Capital Territory, Abuja Nigeria. Petrological investigation of the pegmatites and surrounding host rocks aimed at characterising and understanding field relations and mode of emplacement of the rocks with a view to assess their mineralisation potentials were carried out. From the field observations the pegmatites were characterised into: (1) Pelitic schist-amphibolite hosted pegmatites and (2) Granitoids (orthogneisses) hosted pegmatites, and the granites into (1) the Bakin Ayini (biotite) granites, (2) the Angwan Madugu (biotite-muscovite) granites and (3) the Sabongida (biotite-muscovite) granites. It is clear that those discordantly emplaced in pelitic schists varied in shape and size with length and width ranging from (400-2000m) and (2-20m) respectively, some are huge, isolated, sill-like and flat-lying, whilst those hosted in orthogneisses are narrow, ranging in length (40-1000m) and width (1-4m), crosscutting and vertically oriented along shear zones, which suggest passive emplacement

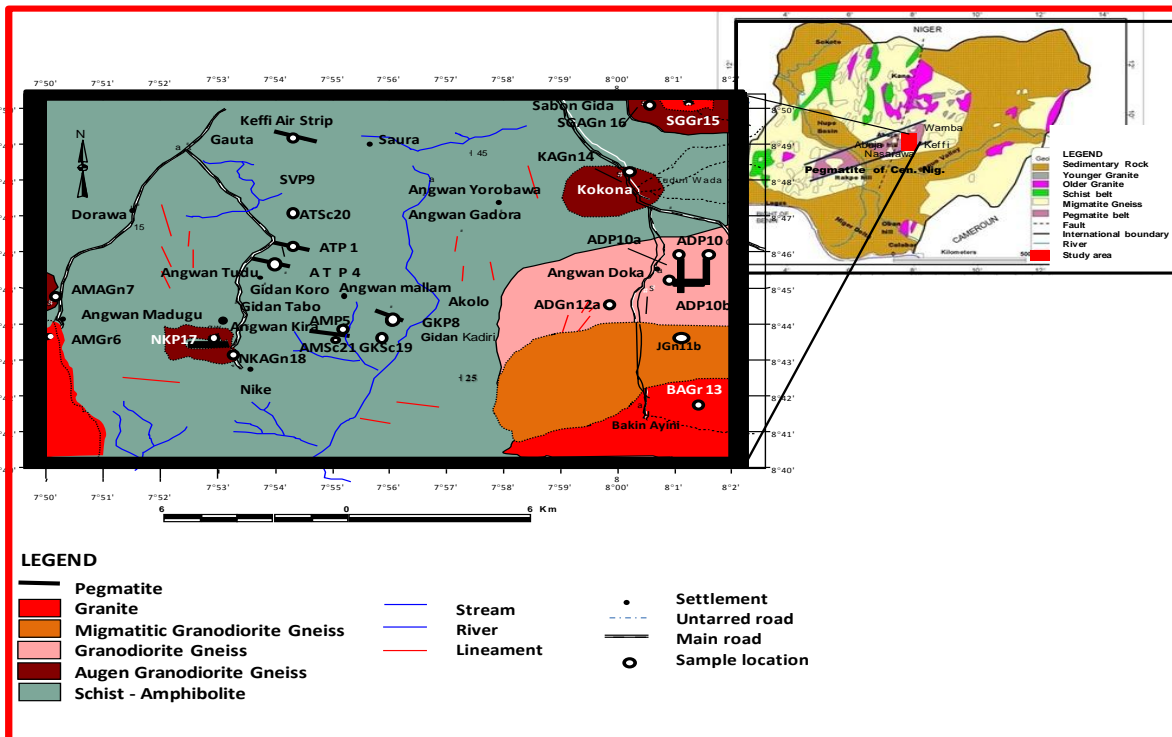
**Keywords:** Pegmatites, emplacement, petrogenesis, characterisation and classification

## 1. Introduction

Nigeria is a tin producing country and over 350,000 tons of cassiterite concentrates have been won from pegmatites in Nigeria between 1912 and 1944 (Jacobson and Webb, 1946). Two tin fields are recognised in Nigeria namely: (a) The tin fields associated with the Younger granite intrusions of Nigeria, and (b) The tin fields linked to the pegmatites of Central Nigeria (Raeburn, 1924). The bulk of the tin from Nigeria comes from the Younger Granites; however a substantial amount of tin is also produced from the pegmatites of Central Nigeria. The Keffi area which lies in the north central pegmatite belt of Nigeria is bounded by 8° 40' 00"N and 8° 50' 10"N and 7° 50' 00"E and 8° 02' 00"E and cover about 326.25 km<sup>2</sup> on a scale of 1:50,000 (see Fig 1.1). Currently exploitation of deposits is being done by small scale miners whose activities are haphazard and uncoordinated. For example, mode of occurrence and relations of pegmatites with host environments are not known and pegmatite types are not distinguished. Also information on the geology of the granites and pegmatites of Keffi area with a view to understanding their characteristics and economic mineral potential is scanty. However, artisanal mining currently going on in the area indicates that the Keffi pegmatites may be economically viable; therefore there is the need to investigate the deposits and assess their economic mineral potential.

The importance of characterisation/classification in understanding the potentials of pegmatite have been demonstrated in several studies (e.g. Ginsburg et al., 1979; Cerny, 1982a; Crouse et al., 1984; Morgan and London, 1987). The Greenbushes and Wodgina fields of Western Australia currently supply the largest share of the world's Ta<sub>2</sub>O<sub>5</sub>, of 30 million tons at 0.047% Ta<sub>2</sub>O<sub>5</sub>, with Sn, Li and kaolin as by products (Simandl, 2002). This development was as a result of the various petrological studies carried out in the area. This present research focused on detailed field investigations which enabled understanding of characterisation, mode of occurrence and emplacement of the pegmatites of Keffi area. This will also provide guidance for fruitful exploration of the pegmatites and to serve as model for exploration of pegmatite veins in similar terrains.

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**Figure 1.1** Geological map of Nigeria showing locations of Pegmatite of Central Nigeria and the Study area (Modified after Kinnaird, 1984)

## 2. Geological Setting

### 2.1 Regional Geology

In order to understand the local geology of the pegmatites of Keffi area, which occur within the basement complex of Central Nigeria, it is important to give a brief review of the regional tectonic and geological setting of Nigerian Basement Complex. The Nigerian Basement Complex forms a part of the Pan African mobile belt and lies between the West African and Congo Cratons and south of the Tuareg shield (Black, 1980). The entire belt including the study area lies in the reactivated region. The tectonic setting of the Nigerian Basement complex has been described (Burke and Dewey, 1972; Caby et al., 1981). Tectonic interpretations supported that the Pan African mobile belt evolved by the collision between the passive continental margin of the West African Craton and the active continental margin of the Tuareg shield about 600 Ma ago (Burke and Dewey, 1972; Caby et al., 1981). It is believed to have experienced deformation, thermal reactivation, metamorphism and emplacement of large volume of granitoids (magmatism) typical of a Himalayan-type during the Pan African Orogeny (600±150 Ma) (Dada, 2006). The general geology of the Nigerian basement complex has been described by many authors (e.g., Jones and Hockey, 1964; Rahaman, 1976; Ajibade et al., 1989; Dada, 2006). The early studies were mainly based on correlating and classifying the rocks into petrological and to some extent geochronological units. However, recent studies particularly by Dada (2006) adopted a multidisciplinary approach in the evolution of the basement rocks and grouped them into four units; the first being the Archaean migmatitic gneiss, followed by the Proterozoic

(schists) rocks, both the migmatites and schist rocks were subjected to Pan African Orogeny (600±150Ma) and intruded by the large masses of Pan-African granitoids and associated Undeformed Felsic and Mafic dykes of late Paleozoic. In general, the basement rocks of Nigeria are believed to be the results of at least four major orogenic cycles of deformation, metamorphism and remobilisation corresponding to the Liberian (2,700 Ma), the Eburnean (2,000 Ma), the Kibaran (1,100 Ma) and the Pan African Cycles (600±150 Ma) (McCurry, 1976; Rahaman, 1976 and Wright, 1976). The first three cycles were characterised by intense deformation and isoclinal folding accompanied by regional metamorphism, which was further followed by extensive migmatitisation, whilst the last cycle was characterised by deformation, metamorphism and granitisation. The closing stages of orogeny were marked by cooling, uplift, fracturing, and by the intrusion of high level volcanic rocks (Jones and Hockey, 1964; Rahaman, 1976, 1988).

## 3. Methods and Materials Used

### 3.1 Field Mapping

Mapping of the area was conducted on a scale of 1:50,000 using Global Positioning System (GPS), compass-clinometers, topographic map, geological hammer, hand lens, hardcover notebook, pen and pencils, camera, measuring tapes, masking tapes and sample bags. The mapping involved reconnaissance survey of the area and detailed mapping of the different rock type's outcrops and sample collection. During the field mapping relations among different rock types and contacts were established. However, not all pegmatite bodies within the area were

mapped in detail because of poor accessibility and high degree of weathering, whilst some had been completely excavated by artisanal miners.

### 3.1.1 Bedrock mapping

The different outcrops investigated include pelitic schists, orthogneisses (granodiorite and augengranodiorite gneisses), granites and pegmatites (see Fig. 1.1). Their lithology, structure, mineralogy, texture (grain size and shapes), foliation, outcrop appearance, and general field conditions were noted. Generally, outcrops were at relatively high altitudes (about 10-20 m) with steep cliffs. Outcrops covered with shrubs and grass were cleared to have relatively clean surfaces to take measurements. Measurements of linearments mostly in the host rocks were taken.

## 4. Local Geology

The pegmatite of Keffi area belongs to the pegmatite belt of north central Nigeria (Jacobson and Webb, 1946) and it belongs to the Pan African Granitoids schist-amphibolites rocks, orthogneisses (augen granodiorite gneiss and granodiorite gneiss) and the granitoids (granites and pegmatites) of Pan-African age. As far as magmatic activity is concerned, the granitoids are emplaced in the basement

rock units in the area. The grade of metamorphism in the metasedimentary rocks of the area varies from greenschists to lower amphibolites grade facies. The main structural features in the area are the penetrative tectonic foliations trending mainly in the N-S, E-W, NE-SW and NW-SE directions, metamorphism, folding, faults, fractures and joints mostly believed to have been reactivated or formed during the Pan African tectonic events (600±150 Ma) (Dada, 2006). In the next section the various rock units, particularly the pegmatites of Keffi area are discussed in detail.

## 5. Petrological Investigations

This section discusses mainly field relations, textures and structures of the various rock types present in the study area. The various rock units identified in the study area consist of pelitic schist- amphibolites, and granitoids (augen granodiorite gneisses, granodiorite to migmatitic granodiorite gneisses, granites and pegmatites). The schists and orthogneisses constitute the host rocks of granites and pegmatites in the area (Table 5.1). Below are detailed description of field relations of the various rock units and Tables 5.1, 5.2 and 5.3 present names and locations of various rock units in the area. Figure 1.1 is the geological map of the area.

**Table 5.1 Name and Locations of Host Rocks in the Study Area**

Serial No.	Rock Name		Location
1	Orthogneisses	Angwan Doka Granodiorite gneiss12(ADGn 12)	N 08° 44' 48.5" and E 008° 00' 46.1"
2		Jama'alu Migmatitic Granodiorite Gneiss 11(JGn 11)	N 08° 44' 58.4" and E 008° 00' 18.2"
3		Kokona Augen Gneisses (KAGn14)	N 08° 47' 43.0" and E 008° 50' 03.6"
4		Angwan Madugu Augen Gneisses (AMAGn 7),	N 08° 44' 14.3" and E 007° 50' 10.0"
5		Sabon Gida Augen Gneisses (SGAGn)	N 08° 50' 39.8" and E 008° 00' 33.1"
6		Nike Augen Gneisses (NKAGn 18)	N 08° 43' 16.0" and E 007° 56' 33.8"
7	Schists-Amphibolites	Gidan Kadiri Schists 19 (GKSc 19)	N 08° 44' 27.1" and E 007° 56' 00.8"
		Angwan Tudu Schists 20 (ATSc 20)	N 08° 44' 14.3" and E 007° 50' 10.0"
		Angwan Mallam Schists 21 (ATSc 21)	N 08° 44' 46.6" and E 007° 55' 20.7"

### 5.1.1 Pelitic Schists-Amphibolites Rock.

The pelitic schists which are generally referred to as “green schist” because of their colour, also contain locally sporadic occurrences of quartzites, quartz-schist and amphibolites. The pelitic schists which host most of the pegmatites dominate the central part of the study area. They are found as xenoliths on the granitoids and outcrop at contacts between the schists and the hosted granitoids around Saura, Angwan Tudu and Angwan Mallam villages. Angwan Madugu augen granodiorite gneiss (AMAGn 7), Nike augen granodiorite gneiss (NKAGn18), Sabon Gida augen granodiorite gneiss (SGAGn 16) and Kokona augen granodiorite gneiss (KAGn 14) appear to have been emplaced in the pelitic schist-amphibolite. They are also bounded to the east by granodiorite to migmatitic gneisses of Angwan Doka (ADGn 12) – Jamaalu migmatitic gneiss (JGn 11) and granites of Bakin Ayini (BAGr 13), and to the south west by Angwan Madugu granite (AMGr6). Pelitic schists-amphibolites contain numerous porphyroblasts of accessory minerals, such as garnet, plagioclase feldspar and amphiboles. The presence of these minerals, together with thin bands of hornblende in the schist suggests that, the metamorphic host rock is in the range of amphibolite facies grade of regional (Barrovian type) metamorphism, during the Pan African orogenic cycle (Ajibade et al. 1989; Akintola and Adekeye, 2008). This indicates the schists were affected by an early episode of medium pressure metamorphism which was followed by an episode of low pressure metamorphism (Ajibade et al. 1989). Conspicuous schistosity defined by the alignment of flaky minerals in sub-parallel to parallel orientation which formed distinct bands of micaceous and quartzo-feldspathic minerals is a common feature in this rock. Generally contacts between host schists and pegmatites appear to be sharp, xenoliths of the older schists were observed in some granites

and pegmatites, mostly near contacts with the host schists (see Fig. 5.12). Compositional changes at the contacts between the schists and pegmatites probably related to the emplacement of the pegmatites such as occurrence of black tourmaline were common. London and Manning (1995) have shown that the phenomenon suggests the pegmatites crystallised from highly fluid-rich melt. The schists generally display strongly developed penetrative tectonic foliations which mostly trend in the N-S and NW-SE and were interpreted as Pan African structures superimposed on earlier tectonic fabrics, which sometimes give contorted appearance to the schists (Akintola and Adekeye, 2008). Most of the pegmatites hosted in the schist tend to be oriented parallel to sub parallel with the directions of foliation in the pelitic schists- amphibolites. However, extreme local variations are common.

### 5.1.2 Augen Granodiorite Gneisses

In the study area, gneissic rocks are represented by orthogneisses (augen granodiorite and granodiorite gneisses to migmatitic granodiorite gneiss). The north east of the area is typified by the Sabon Gida and the Kokona augen gneisses whilst Angwan Madugu and Nike augen gneisses dominate the west and central parts of the mapped area respectively (Fig. 1.1). Among these rock types in the area, it is only the Nike augen gneiss that host pegmatites. These rocks occur as jointed massive outcrops with xenolith and porphyritic plagioclase feldspar forming the ‘augen’ structure. The directional structure in the foliated rocks was probably imposed during the later stages of Pan African tectonic activity (Kuster, 1990, Garba, 2007, Adekeye and Akintola, 2007). These lineaments are mostly oriented in the NW-SE, E-W and NE-SW which coincide with the orientations of the hosted pegmatites. Contacts with their host rocks were not observed in the area.



(a)



(b)

**Fig. 5.1:** (a) Shows Angwan Madugu augen gneiss with phenocryst of plagioclase feldspar (AMAGn 7). (b) Shows photograph of Kokona augen gneiss containing phenocryst of zoned grain of plagioclase feldspar. The pen is a 15cm and hammer is 35 cm long.

### 5.1.3 Granodiorite-Migmatitic granodiorite gneisses.

Angwan Doka-Jamaalu granodiorite to migmatitic granodiorite gneisses crop out around Angwan Doka and Jamaalu villages respectively. These circular massive rocks that host the Angwan Doka pegmatites were emplaced in the pelitic schist-amphibolite rocks located to the east of the main area of pegmatites concentration (see Fig. 1.1). At Angwan Doka the outcrop is granodioritic and hence referred to Angwan Doka Granodiorite gneiss (ADGn12). Towards the south of Angwan Doka village near Jamaalu village the granodioritic gneiss become migmatitic and form a mappable unit, Jamaalu Migmatitic Granodiorite Gneiss (JGn 11). But there were no visible gradational contact observed. The gneisses as well as other older rocks within the shear zone were mostly mylonitised. The mylonitisation

occur along the strike-slip fault with a dextral sense of movement in the migmatitic granodiorite gneiss of Jamaalu village (see Fig. 5.2 (b)). The migmatitic granodiorite gneiss consists of complexly alternating bands of quartzofeldspathic veins (see Fig. 5.2 (b)). Unlike the Angwan Doka granodiorite gneiss, Jamaalu migmatitic granodiorite gneiss do not host any pegmatite in the area. Generally these rocks lack the prevalence of "augen" texture and differ in their textural features with the augen granodiorite gneisses. Orientations of lineaments in the granodiorite-migmatitic granodiorite gneisses are commonly in the N-S, E-W and NE-SW directions. These directions correspond with the orientations of the hosted pegmatites (see Fig. 5.1).



**Fig. 5.2** (a) Photograph of Angwan Doka Granodiorite gneiss (ADGn 12). Diameter of coin is 2.5cm and (b) shows Jamaalu migmatitic granodiorite gneiss (JGn 11).

### 5.1.4 Granites

The sparsely distributed granites which were emplaced in both the pelitic schists-amphibolite and orthogneisses surround pegmatite bodies in the Keffi area (see Fig. 1.1). To the east of the mapped area lies the Bakin Ayini granite and Angwan Madugu granite which dominates the south

western area. The elongated Sabon Gida granite lies to the extreme north eastern part of the study area. Two types of granites were identified; the biotite granites (Bakin Ayini granite) and the biotite-muscovite granites (Angwan Madugu and Sabon Gida granites). Below is a table of names and locations of granites in the area

**Table 5.2 Name and Locations of Granites in Keffi Area**

Serial No.	Names	Locations
1	Bakin Ayini Granite13 (BAGr 13)	N 08° 41' 28.8" and E 008° 01' 39.2"
2	Sabon Gida Granite 16 (SGGr 16)	N 08° 50' 39.8" and E 008° 00' 38.0"
3	Angwan Madugu Granite 6 (AMGr 6)	N 08° 43' 20.3" and E 007° 49' 46.6"

#### Bakin Ayini granite (biotite granites)

The Bakin Ayini round and elongated bodies appear to have been emplaced discordantly within the orthogneisses. These elongated bodies were oriented parallel to sub parallel with the lineaments of the host rocks predominantly in E-W and NE-SW directions. No evidence of foliation was

observed in these rocks. Some of these masses contain pods with characteristic texture of pegmatite; with well-developed fine-coarse grains of perthitic microcline, subhedral to euhedral crystals of quartz in the field. The general brownish colour appearance of these rocks may be due to alteration of the alkali feldspar and iron-leaching of

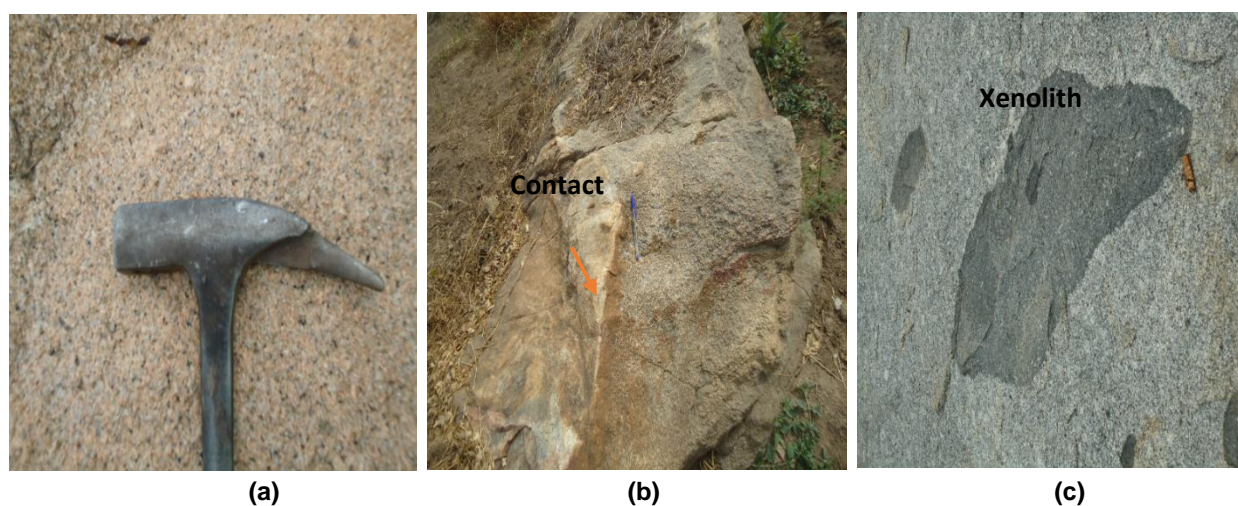
the dominant biotite flakes of the rock. Although no contact with the host rock was observed, however their mode of occurrence suggest emplacement along the shear zone.

#### Angwan Madugu (biotite-muscovite) granites

Angwan Madugu granites crop out as small elliptical bodies, discordantly emplaced within the pelitic schists. Angwan Madugu granites are biotite-muscovite granites like Sabon Gida granite, but slightly vary in terms of texture, structure and mineralogy. These rocks are coarser, non-foliated and contain larger crystals of biotite and more rare minerals (mostly in cavities) than the Sabon Gida granites. These differences suggest them being an off-shoot of Bakin Ayini biotite granites (BAGr 13). The outcrops were jointed and contacts with pelitic schists-amphibolite were sharp (see Fig. 5.3 (b)). These rock masses are slightly darker than the Sabon Gida granite.

#### Sabon Gida granite (biotite-muscovite) granite

Sabon Gida granite are highly foliated and elongated masses discordantly emplaced in Sabon Gida augen gneiss. The highly fractured and jointed masses on the out crop appear lighter in colour and finer in crystal size compared to biotite-muscovite granite of Angwan Madugu, probably due to its lower content of biotite. Furthermore, inclusions of country rock have been observed in some cases, e.g. xenolith of pelitic schists (see Fig 5.3 (c)). Foliation is a distinct feature of this granite. The rock masses are elongated, parallel to sub parallel with the foliation of the host rock and contacts between the granite and the host rock are sharp. These features have been reported as characteristics of the Older Granite suites in Nigeria (Truswell and Cope, 1963).



**Fig. 5.3:** Are photographs of (a) Bakin Ayini granite (BAGr13) along Kofan Gwari-Bakin Ayini Road. Head of hammer is 12cm. (b) Photograph of Angwan Madugu granite (AMGr 6) along Keffi-Nasarawa road. (c) Photograph of a slightly foliated fine grained Sabon Gida granite (SGGr15). Length of jackknife 10cm.

#### 5.1.5 Pegmatites

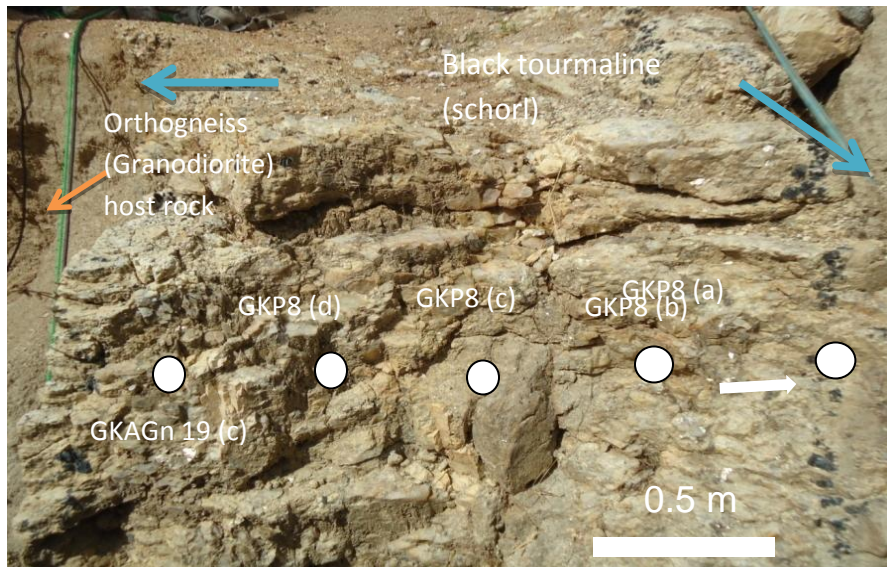
There are nine pegmatites identified in Keffi area namely: Gidan Kadiri (GKP8), Angwan Mallam (AMP5), Nike (NKP17), Angwan Tudu (ATP1) and (ATP4), Angwan Doka (ADP10A), (ADP10B) and (ADP10C) and Saura village (SVP9). These pegmatites were emplaced in two main rock terrains; metamorphic (pelitic schists-amphibolites) and the igneous (augen granodiorite-granodiorite gneisses) terrains. Below are detailed description of field features of these pegmatites Table(5.3) and Figs (5.9-5.17). Directions of thick arrows (white and black) indicate continuity of sample locations into the host rocks.

**Table 5.3 Name, Location and other Field Features of Pegmatites in Keffi Area**

## Gidan Kadiri Pegmatite 8 (GKP 8)

S/N	Field features							Hand specimen description and Major mineral composition	
	Name	Location	Orientation		Size		Contact with Host Rock and other features		Host Rock
			Strike	Dip	Length	Thickness			
1	Gidan Kadiri Pegmatite 8(GKP8) (see Fig.5.1)	N 08°44'27.1" and E 007°56'00.8"	N75°E	34°SE	40m long	3m wide	Sharp and aligned with black tourmaline	Pelitic schist-amphibolite	Coarse grained, light in colour, coarse grained. Constituted of K-feldspar+plagioclase + quartz ± biotite and black tourmaline
2	Angwan Mallam Pegmatite 5 (AMP5)(see Fig.5.4)	N 08°44'46.6" and E 007°55'20.7"	N66°W	85°S W	100m long	6m wide	Sharp aligned with black tourmaline; Flat-lying and undulating with Pinch and swell.	Pelitic schist-amphibolite	Light coloured, very coarse grained texture. Composed of K-feldspar + plagioclase + quartz + muscovite ± biotite and Black tourmaline.
3	Nike Pegmatite 17 (NKP17) (see Fig.5.7)	N 08°44'27.1" and E 007°56'00.8"	N87°E	35°S W	110m long	3m wide	Sharp	Augen granodiorite gneiss	Light coloured, Coarse grained and cracks. Observable Major minerals comprise of K-feldspar + muscovite + quartz + biotite both black and green coloured tourmaline.
4	Angwan Tudu Pegmatite 1 (ATP1) (see Fig.5.10)	N 08°45'02.9" and E 007°54'13.1"	N44°W	86°SE	1km long	4m wide	Sharp with narrow zone of alteration; Zoned, Pinch and swell structure	Pelitic schist-amphibolite	Grey colour, medium to coarse grained texture, anhedral to sub-hedral crystals. Observable minerals consist of quartz + microcline + fine muscovite + green and black tourmaline.

5	Angwan Tudu Pegmatite 4 (ATP 4) (see Fig.5.13)	N 08°45'11.3" and E 007°54'00.3"	N46°W	85°NE	500m long	2m wide	Sharp with slight alteration	Pelitic schist-amphibolite	Coarse grained, light coloured; major minerals observed include: plagioclase feldspar + K-feldspar + quartz + muscovite, lepidolite + black tourmaline + green to red coloured tourmaline.
6	Angwan Doka Pegmatite 10A (ADP10A) (see Fig.5.16)	N 08°45'16.0" and E 008°00'56.0"	N03°E	56°NW	700m long	1m wide	Sharp	Granodiorite gneiss	Coarse to medium grained, reddish to greyish colour. Consist mainly of quartz+ plagioclase + K-feldspar + fine and large muscovite+ green tourmaline
7	Angwan Doka Pegmatite 10B (ADP10B) (see Fig.5.24)	N 08°45'11.8" and E 008°00'56.0"	N88°E	53°SW	500m long	3m wide	Sharp; Zoned, Cross-cutting other pegmatites, fractures and joints	Granodiorite gneiss	Coarse to very coarse grained, light colour. Major mineral consist mainly of quartz+ plagioclase + K-feldspar + lepidolite + fine and large muscovite + green tourmaline +garnet
8	Angwan Doka Pegmatite 10C (ADP10C) (see Fig.5.30)	N 08°45'14.5" and E 008°00'54.0"	N03°E	61°NW	1km long	3m wide	Sharp	Granodiorite gneiss	Coarse grained texture, light coloured. Coarse to medium grained, reddish colour. Consist mainly of quartz + plagioclase + lepidolite + K-feldspar + fine muscovite + black and green tourmaline
9	Saura Pegmatite 9 (SVP 9)	N 08°48'55.1" and E 007°54'	N38°W	89°	=1.5 km	10m	Sharp and aligned with black	Pelitic schist-	Coarse to medium grained, reddish colour. Consist mainly of quartz + plagioclase + lepidolite + K-feldspar +



**Fig. 5.4:** Photograph of pegmatite vein at Gidan Kadiri (GKP 8)

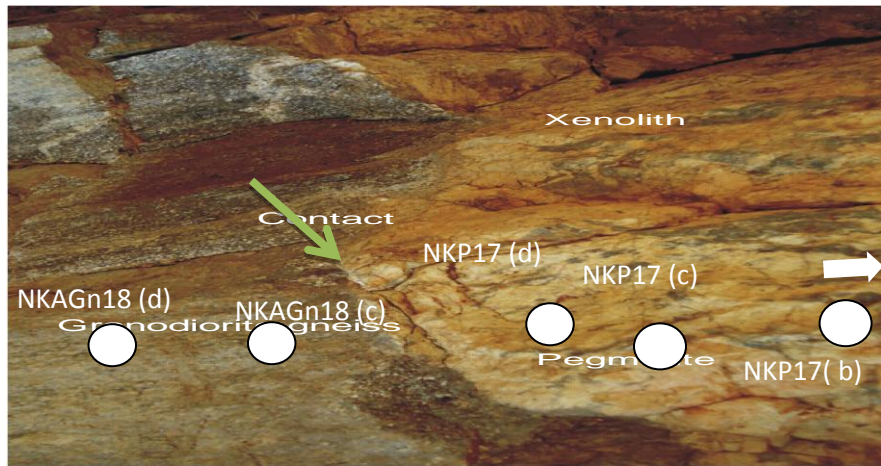
Angwan Mallam Pegmatite 5 (AMP5)



**Fig. 5.5:** Photograph of Angwan Mallam Pegmatite (AMP 5). The hammer is 35 cm long.

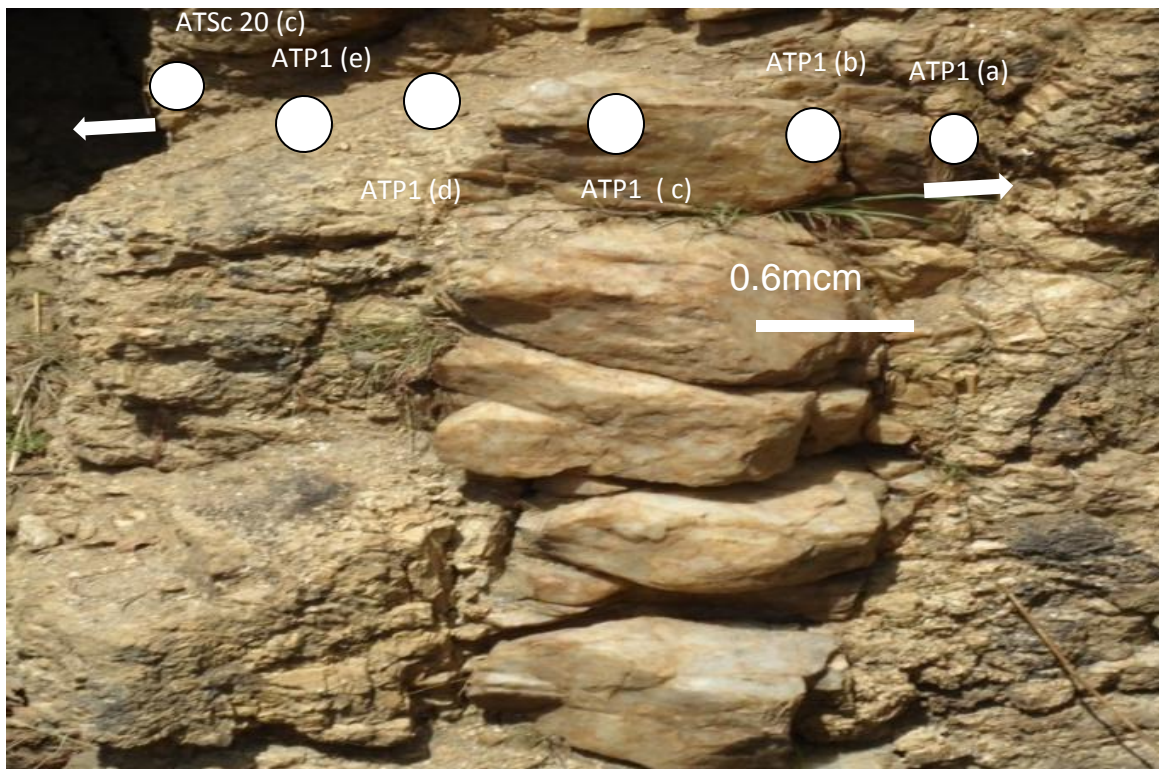
Nike Pegmatite 17 (NKP 17)





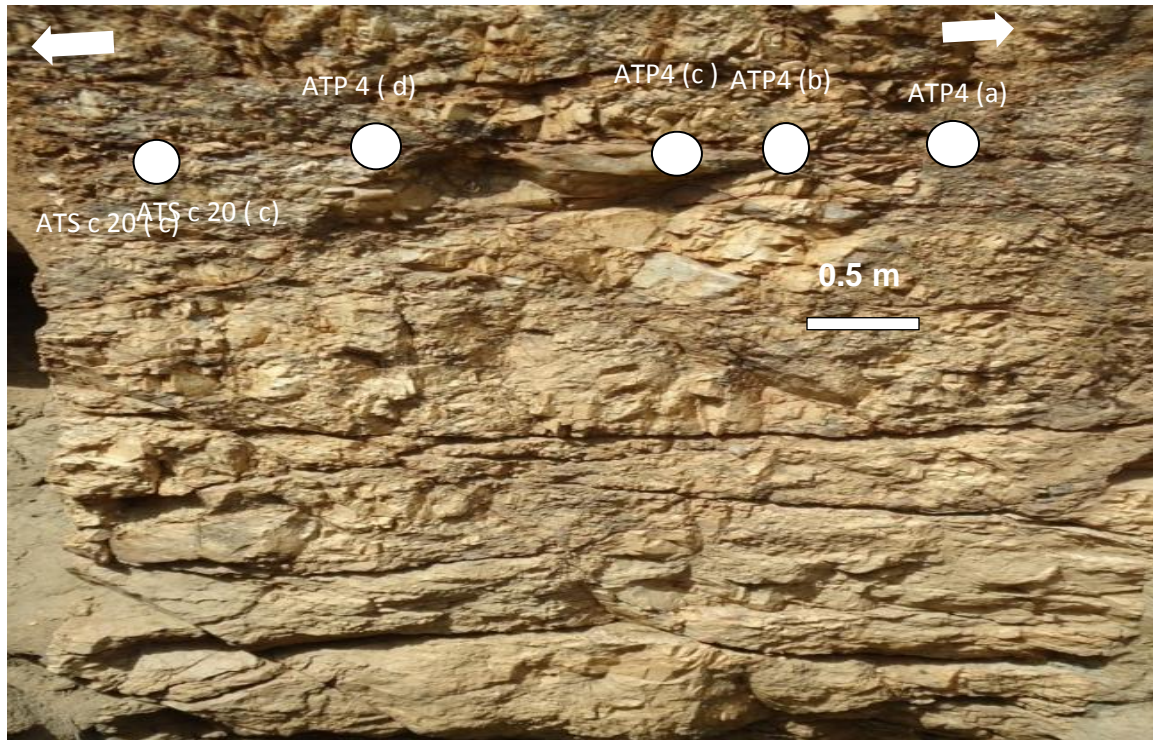
**Fig. 5.6:** Photograph of Nike pegmatite showing the contact between the pegmatite and the granodiorite gneiss (host rock), with xenolith of the host rock in the pegmatite

Angwan Tudu Pegmatite (ATP1)



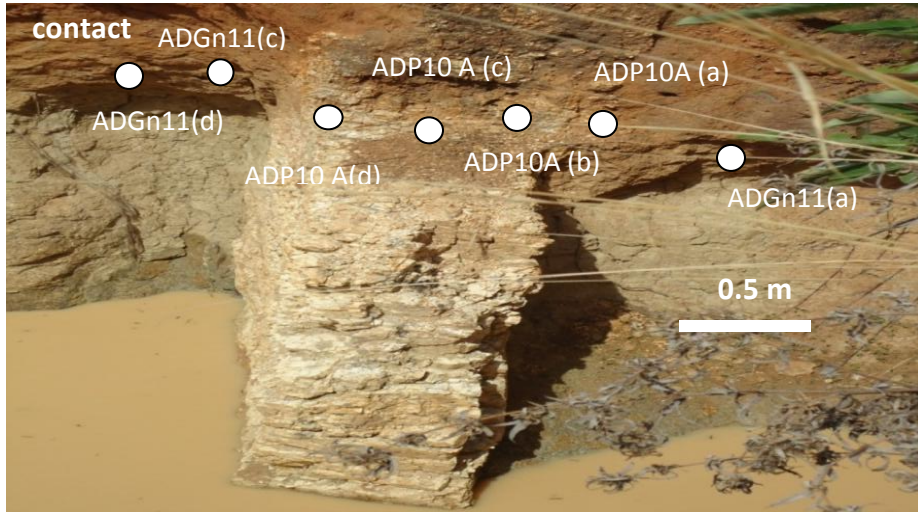
**Fig. 5.7:** Photograph of Angwan Tudu Zoned Pegmatite (ATP1) with a very Coarse Quartz Core.

Angwan Tudu Pegmatite (ATP4)



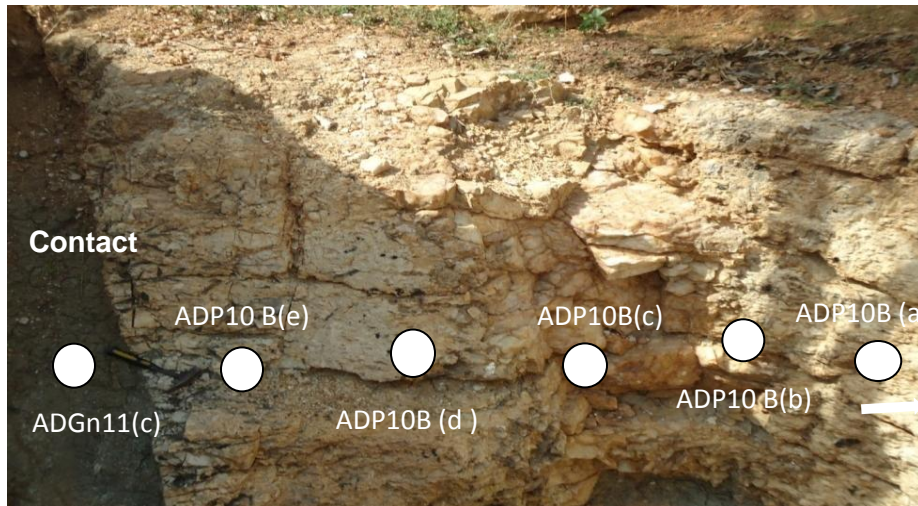
**Fig 5.8:** Photograph of Angwan Tudu Pegmatite (ATP 4)

Angwan Doka Pegmatite (ADP10A)



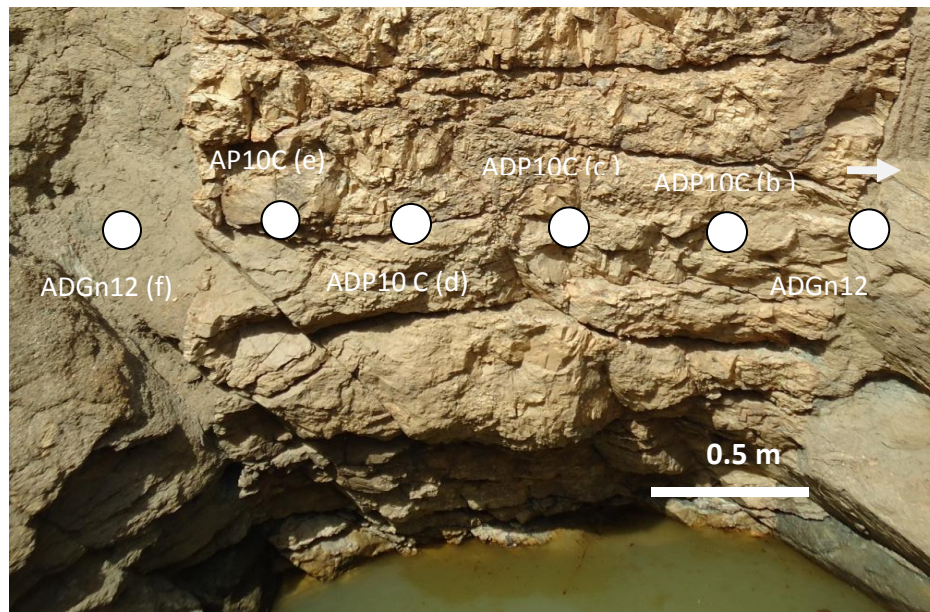
**Fig. 5.9:** A photograph of cross-section of an inclined Angwan Doka Pegmatite (ADP10A)

Angwan Doka Pegmatite (ADP10B)



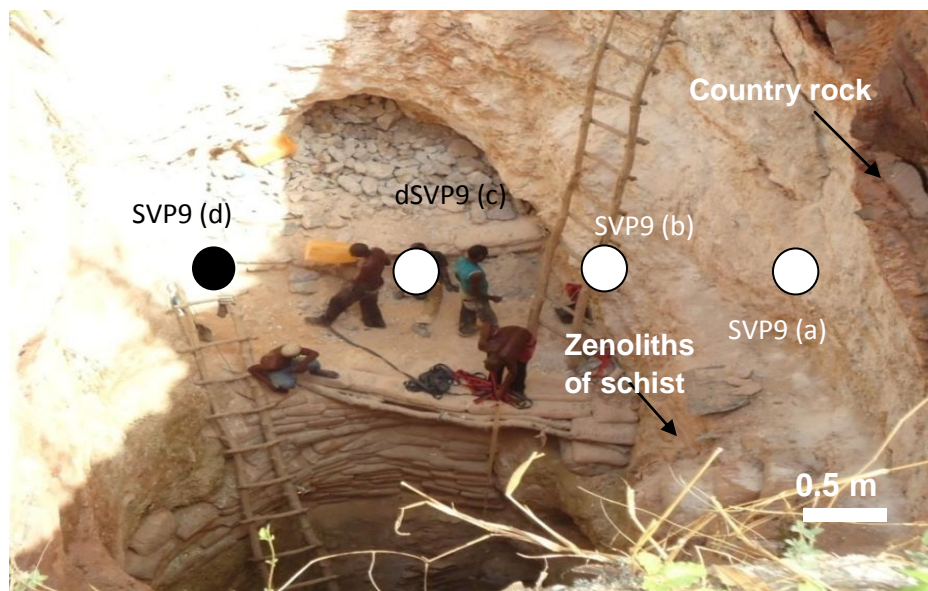
**Fig. 5.10:** Photograph of Angwan Doka pegmatite vein (ADP10B) showing a sharp contact with the host rock (granodiorite gneiss).

Angwan Doka Pegmatite (ADP10C)



**Fig. 5.11:** Photograph of a cross-section of an inclined Angwan Doka Pegmatite dyke (ADP10C) showing sharp contact with the granodioritic gneiss. The length of hammer is 35 cm.

Saura Village Pegmatite (SVP9)



**Fig. 5.12:** Photograph of plan view of a pit on pegmatite vein at Saura with zenoliths of schist within weathered portion of the pegmatite near the contact (SVP 9)

## 6. Discussion

### 6.1 Classification of Pegmatites of Keffi Area

#### 6.1.1 Introduction

Pegmatites have been classified on various parameters such as the depth of consolidation or emplacement, the type of mineralisation relation to the igneous processes and the metamorphic environment, in which they are frequently found (Ginsburg et al., 1979; Cerny, 1982a ). In addition, pegmatites are also classified depending on their major, accessory, rare-metal mineral constituents and geochemistry. Therefore pegmatites of Keffi in this study were classified or characterised on the bases of environment of their emplacement as described below.

#### 6.1.2 Classification on the basis of environment of emplacement

Pelitic schist-amphibolite hosted pegmatites: These pegmatites Angwan Tudu pegmatite 1(ATP1), Angwan Tudu pegmatite 4 (ATP4), Angwan Mallam pegmatite 5 (AMP5), Gidan Kadiri pegmatite 8 (GKP 8) and Saura village 9 (SVP9). From field observations, this category of pegmatites occur parallel to sub-parallel to the foliation of the host rocks mainly in the NW-SE direction and are relatively flat-lying, with pinch- and -swell structure, suggesting them being sills. This category of pegmatites ranges in length from 500 m - 1.5 km and thickness of 4 m - 100 m. The transition from pegmatite to host rock which is usually abrupt indicates a sharp contact (see Figs 5.6 and 5.10). The pegmatite-country rock contacts in most of the pegmatites of this category are recognised by the presence of black tourmaline along a narrow zone (see Figs. 5.4 and 5.5). This is an indication of contact alteration. London (1990) suggested that the occurrence of black tourmaline (schorl) at the borders of pegmatites was by the mixing of pegmatite derived component (Na, B, Al, and Si) and wallrock-derived components (Mg, Fe). In addition, the occurrence of biotite, tourmaline and amphibole (hornblende) across the boundaries also confirms the slight pegmatite-country rock alteration effect. However, the pegmatite-country rock alteration's effect is not widely spread on both sides of the contacts. This suggests that the alteration effects and the similarities of minerals at the contacts were probably derived from the influence of propylitic alteration induced by the emplacement of pegmatites rather than gradational transition as in the case of metamorphic changes from the surrounding rocks into the hosted pegmatites (transition contact), which supports metamorphic origin. Granitoids (orthogneisses) hosted pegmatites: From the field observations, the four pegmatites identified in this category include the Angwan Doka pegmatite 10A (ADP10A), AngwanDoka pegmatite 10B (ADP10B), Angwan Doka pegmatite 10C (ADP10C) and Nike pegmatite 17 (NKP17). These pegmatites were emplaced in two different granodiorite gneisses; the augen granodiorite and the granodiorite gneisses. Angwan Doka (ADP10A), (ADP10B), (ADP10C) pegmatites were emplaced in the granodiorite gneiss, whilst augen granodiorite gneiss hosted Nike (NKP17) pegmatite. Furthermore, field observations show that these pegmatites were usually small but regular tabular shapes, characterised by intersecting bodies of few kilometres in

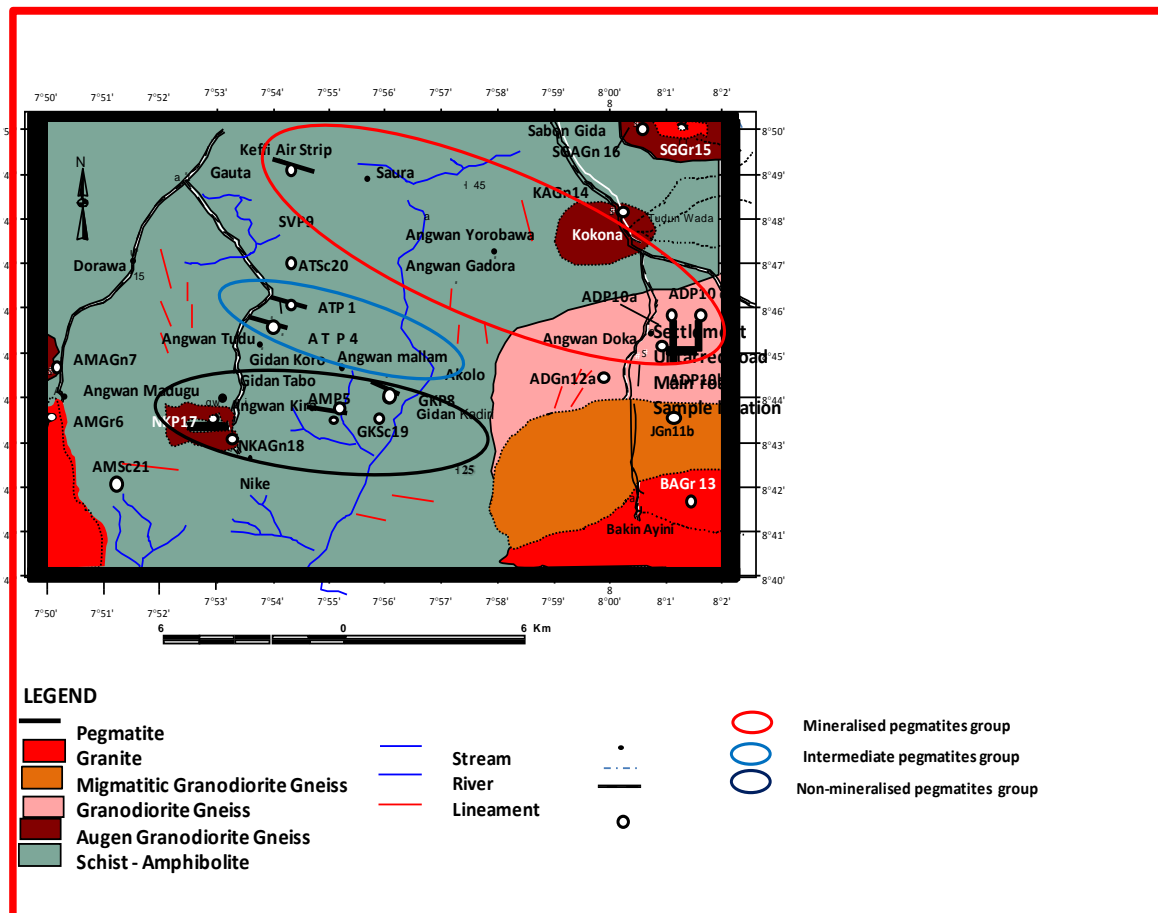
length (40 m -1000 km) and width of (1-4 m). The cross-cutting relationships did not indicate any age relationship; rather it was a simple in-filling of existing fractures by the intruding pegmatitic melt. These pegmatites trend in two main directions a N-S and E-W, dipping in varying directions at angles ranging from 10-25° (see Figs 5.9 and 5.10). The above-mentioned features suggest them being dykes. Similarly, these pegmatites show very sharp pegmatite-country rock contacts, characterised with narrow alignment of black tourmaline along the contacts on both sides i.e. at foot wall and hanging wall, as in the case of pelitic schist-amphibolite hosted pegmatites. Field observation of the two identified categories of pegmatites (1) pelitics schist-amphibolite hosted pegmatites and (2) granitoids (orthogneisses) hosted pegmatites suggest that they are sills and dykes respectively. Almeida (2007) also suggested similar features as criteria for discrimination of pegmatites on the basis of environment of emplacement of granitic rocks. In addition, the schist-amphibolite hosted pegmatites show slightly widely altered contacts, probably due to the fissile nature of the host rock, whilst those hosted in orthogneisses pegmatites commonly exhibit very sharp contacts. But, generally they all indicate slight compositional changes related to pegmatites' emplacement at the wallrocks of the pegmatites and the host rocks, typified by the narrow alignment of black tourmaline. However, with respect to major changes related to mineral compositions of the main pegmatite bodies in terms of major minerals, the pelitic schist-amphibolite hosted pegmatites have essentially remained similar to those hosted by orthogneisses. For example, Nike pegmatite 17 (NKP17) which shows simple mineral composition is hosted in orthogneisses (granitoids) like those complexly mineralised pegmatites of ADP10A, ADP10B and ADP10C. Conversely the simple mineral composed Angwan Mallam pegmatite 5 (AMP 5) and Gidan Kadiri pegmatite 8 (GKP 8) are hosted in pelitic schists-amphibolites as those of complexly mineralised pegmatite of Saura village 9 (SVP 9). Therefore, it can be concluded that the two categories of pegmatites (pelitic schist-amphibolite hosted pegmatites and orthogneisses hosted pegmatites) despite their little structural variation, on the basis of mineralogical content, the pegmatites of Keffi area were not influenced by their host rocks of emplacement.

### 6.2 Regional Zonation

Field investigation and hand specimen description indicate that the pegmatites from Keffi area show composition of major minerals (hand specimen) such as K-feldspar, plagioclase feldspar, quartz, muscovite, biotite, lepidolite and tourmaline in varying degrees. However some minerals appear to be restricted to specific pegmatites e.g biotite, lepidolite and coloured variety of tourmaline (Table 5.3). Starting from those closest to the granite plutons, the Nike pegmatite 17 (NKP 17), Gidan Kadiri pegmatite 8 (GKP 8), Angwan Mallam pegmatite 5 (AMP 5) to the intermediate Angwan Tudu pegmatite 1 (ATP 1) and Angwan Tudu Pegmatite 4 (ATP 4) and the farthest Angwan Doka pegmatite10B (ADP 10B), Angwan Doka pegmatite10A (ADP 10A) Angwan Doka pegmatite10C (ADP 10C) and Saura village pegmatite (SVP 9). For example, Biotite seems to be restricted to pegmatites closest to the granite plutons in the area i.e. Nike pegmatite

17 (NKP17), Angwan Mallam pegmatite 5 (AMP 5) and Gidan Kadiri pegmatite 8 (GKP 8) and were not observed in the intermediate and farthest pegmatites (see Table 5.3). Also it was observed that lepidolite begun to appear in pegmatites of Angwan Tudu pegmatite 1 (ATP 1) and Angwan Tudu Pegmatite 4 (ATP 4) and became pervasive in the distal Angwan Doka pegmatite10B (ADP 10B), Angwan Doka pegmatite10A (ADP 10A) Angwan Doka pegmatite10C (ADP 10C) and Saura Village pegmatite (SVP 9). No lepidolite was observed in the Nike pegmatite 17 (NKP17), Angwan Mallam pegmatite 5 (AMP 5) and Gidan Kadiri pegmatite 8 (GKP 8). Similarly tourmaline variation in the pegmatites of Keffi area was observed (see Table 5.3). Although black tourmaline (schorl) in the pegmatites and at the contacts appears to be common

features of most of the pegmatite of Keffi area (see Figs. 5.4, 5.5, and 5.10), coloured variety begins to appear in the Angwan Tudu pegmatites ATP 1 and ATP 4 and become more evolved in pegmatites of ADP 10B, ADP 10A, ADP 10C and SVP 9 (see Table 5.3). Several work in most pegmatite fields have observed similar trend in variation of mineral composition (Varlamoff, 1972; Cerny 1982a, 1991a; Cerny and Meintzer 1988; Norton and Redden 1990; Barker, 1998; London, 2005). All these observed variations in mineralogical composition suggest that pegmatites of Keffi are regionally zoned and can be categorised as (1) Non mineralised (NKP17, GKP 17 and AMP 5) (2) Intermediate pegmatites (ATP1 and ATP4) and (3) Mineralised pegmatites (ADP10A, ADP10B, ADP10C and SVP9).



**Figure 6.1:** Geological map of Nigeria Showing Regional Zonation Pattern (a) Non Mineralised, (b) Intermediate and (c) Mineralised Pegmatites of Keffi Area. (Modified after Kinnaird, 1984).

### 6.3 Mode of Occurrence of Granites and Pegmatites of Keffi Area

Field investigations have shown that granites and pegmatites of Keffi area occur along or parallel to sub-parallel with the predominant tectonic shearing, mainly in the N-S, NW-SE, E-W and NE-SW directions, whilst few cut across these ancient lineaments (see Fig.1.1). Also, the mylonitisation and migmatitisation commonly observed along N-S, E-W and NE-SW striking shear-zones, evident by the mylonites in Jamaalu migmatitic granodiorite gneiss and foliations observed in the rocks (see Fig.5.2 (b)), further

confirmed the emplacement of the granitoids along these shear zones to be linked to orogenic processes. Garba (2003) related the genesis of the rare-metal and the barren pegmatites and the gold mineralisation in the Pan African basement of northern Nigeria both in space and possibly in time by late Pan African tectonics, and also concluded that the development of transcurrent fault conjugate systems (Kalangai transcurrent fault) in the Kushaka schist belt is related to it. Kuster (1990) reported similar observation in Wamba pegmatite field and related it to the closely associated Pan African tectonic lineaments. In addition,

Kuster(1990) reported dextral movement along NE-SW striking faults and sinistral NW-SE to NNW-SSE striking fault in the Wamba pegmatite field. In this study, similar dextral sense of movement in NE-SW direction was also observed in Jamaalumigmatitic granodiorite gneiss (see Fig.5.2 (b)).

#### 6.4 Emplacement of the Granites and Pegmatites of Keffi Area

From the tectonic setting and the style of occurrences of granites and pegmatites along shear zones in Keffi area (see Fig 1.1), it is most likely that the resultant granitic magma was under pressure, due to the nature of its composition characterised by viscosity, water content and the state of stress at the source region. This might have taken advantage of the deep fractures and planes of weakness that characterised the shear zones for the emplacement of the granites and pegmatites in the Keffi area. It is also likely that this has taken place when the late-tectonic activity was still active and host rocks were still in a semi-plastic state (Kuster, 1990). All these might have facilitated the movement of the already resultant compressed granitic melt into the shallow region of the dilatant country rocks as a result of the density difference between the melt and the host rocks. Furthermore, observation of xenoliths of the host rocks, sharp contacts with host rocks, deformation of some minerals and development of minor cracks in both the granites and pegmatites, suggest a slight force during ascension and emplacement of melt along shear zones from depth below.

#### 7. Conclusion

In the light of the above discussions the following conclusion can be made:

- (1) On the basis of their host rock environment the pegmatites were grouped into: (1) Pelitic schist-amphibolite hosted pegmatites and (2) Granitoids (orthogneisses) hosted pegmatites; and the surrounding granites into: (1) the Bakin Ayini (biotite) granites, (2) the Angwan Madugu (biotite-muscovite) granites and (3) the Sabongida (biotite-muscovite) granites
- (2) Field observations show that some pegmatites of Keffi area were discordantly emplaced in the pelitic schists and have varied shapes and sizes with length and width ranging from (400m-2000m) and (2-20m) respectively. Also those hosted in pelitic schists-amphibolite are huge, isolated, sill-like and flat-lying; whilst majority of the orthogneisses hosted ones are narrow, crosscutting and inclined.
- (3) Also field and mineralogical observations (hand specimen) show that the pegmatites of Keffi area are regionally zoned into; group I (Non-Mineralised), group II (Intermediate) and group III (Mineralised) pegmatites.
- (4) The tectonic setting and style of occurrences of granites and pegmatites along the shear zones in the area, suggest that emplacement of the granites and pegmatites in the Keffi area has taken advantage of the deep fractures and planes of weakness in the host rocks.

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