THE GEOLOGY AND GEOCHEMISTRY OF IRONSTONE AND KAOLIN DEPOSITS IN SHEET 85 (UDUBO), BAUCHI STATE

BY

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF SCIENCE, GEOLOGY (MINERAL EXPLORATION)

JUNE, 2000

DECLARATION

I declare that this thesis, is my own work and has not been presented for another degree or diploma to any other University or Institution. Information utilized from both published and unpublished works, are duly acknowledged in the text.

Signature

30/6/2022
Date

CERTIFICATION

This project/thesis titled: Geology and Geochemistry of Taranji Ironstone and Tumfure kaolin deposit in sheet 85 (Udubo) by Mrs. F.A. Adeoye, satisfies the regulation for the award of M.Sc Geology (Mineral Exploration) of Ahmadu Bello University and is approved for it's contribution to knowledge and literary presentation.

Chairman Supervisory Committee	Date 12/01/01
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DEDICATION

I dedicate this project to my parents

LATE MR. ANDREW FAMBO - FATHER

MRS. ABIGAIL .O. FAMBO - MOTHER

LATE MADAM ESTHER OMOYE - GRANDMOTHER

also to

MR. PETER ADEOYE - MY HUSBAND

AND

MY CHILDREN

ACKNOWLEDGMENT

First and foremost, I glorify Almighty God, who preserved my life to see the completion of this project hale and hearty also, for granting me abundant journey mercies throughout the period of study.

I give thanks to The Director of Geological Survey Department - Dr. M.O. Ojo, for permission to study.

My profound gratitude goes to my supervisors Dr. J.I. Omada and Dr. A.E. Ikpokonte - for their constructive criticisms, advices and for reading through the script.

I sincerely acknowledge the words of encouragement of Professor E.C. Ike, Dr. I. Garba, Mr. S. A. Alagbe, Mr. E. A. Bala and Mr. T. Najime, Mr. E. O. Obiosio, Dr. I. Funtua, Dr. U. A. Danbatta, Mr. H. Hamza infact, the entire staff of Geology Department, Ahmadu Bello University, Zaria.

The hospitality of Sarkin Jalam - Alhaji Saleh Mohammed and his second in command - Alhaji Maigari Madubi, Sarkin Tarmasua and late Sarkin Udubo who all, provided accommodation during the fieldwork is highly appreciated.

Above all, I am most grateful to my husband - MR. PETER ADEOYE and our children who endured untold hardship and inconveniences caused by my absence from home during the period of study.

Finally, I gratefully appreciate the effort of all my friends and well-wishers who contributed in one way or the other to the successful completion of this project.

Thanks and God bless.

ABSTRACT

Taranji in Udubo area of Bauchi State is located in the Chad Basin of north-eastern Nigeria. The area is covered by clay, ironstone, sandstone and loose sand.

The aim of the project is to determine the extent, quality and possible uses of the clay and ironstone in the area. This involved geological mapping of the area, the geochemical studies of the clay and the ironstone and the geotechnical studies of the clay.

Vertical profiles of twenty (20) hand-dug pits of average of one thousand (1,000 m) were examined and sampled along the profiles. In addition, two boreholes drilled to a depth of 48.8 m and 38.8 m respectively, located in Walwal area, in Gamawa Local Government Area of Bauchi State by the Geological Survey of Nigeria, were sampled and studied.

Physical observations of rocks indicate that haematite is the main mineral of the ironstone while quartz occurs as impurity. Kaolinite is the main minera of the clays. The clay occurs as massive deposit in the area of study.

Data from boreholes and cores indicate that the ironstone occurs in four layers with a total thickness of 6.72 m. Medium-grained older granite was struck at a depth of 48.8m while drilling, signifying that the thick pile of sediments in he Chad Basin is underlain by rocks of the Basement Complex in this area.

The wet chemical data indicate a direct relationship between the compositional variation of the oxides, the purity of the ironstone occurrence and kaolin deposit. X-ray diffractometry result corroborates result of geological mapping that haematite is the major mineral while quartz occurs as impurity.

Geotechnical analysis indicates that the clay has tough tensile trength with liquid limit of 29.25% and plastic limit of 13.04% and average linear shrinkage of 5.75%.

Structures observed were beddings, very few cross-laminations in sandstones, folds oolitic and pisolitic textures in the ironstone..

Drilling was discontinued due to lack of funds, therefore, the exact thickness of the overburden and the ironstone could not be ascertained at various locations to determine exact or accurate reserves of the deposit.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Location, Extent and Accessibility.

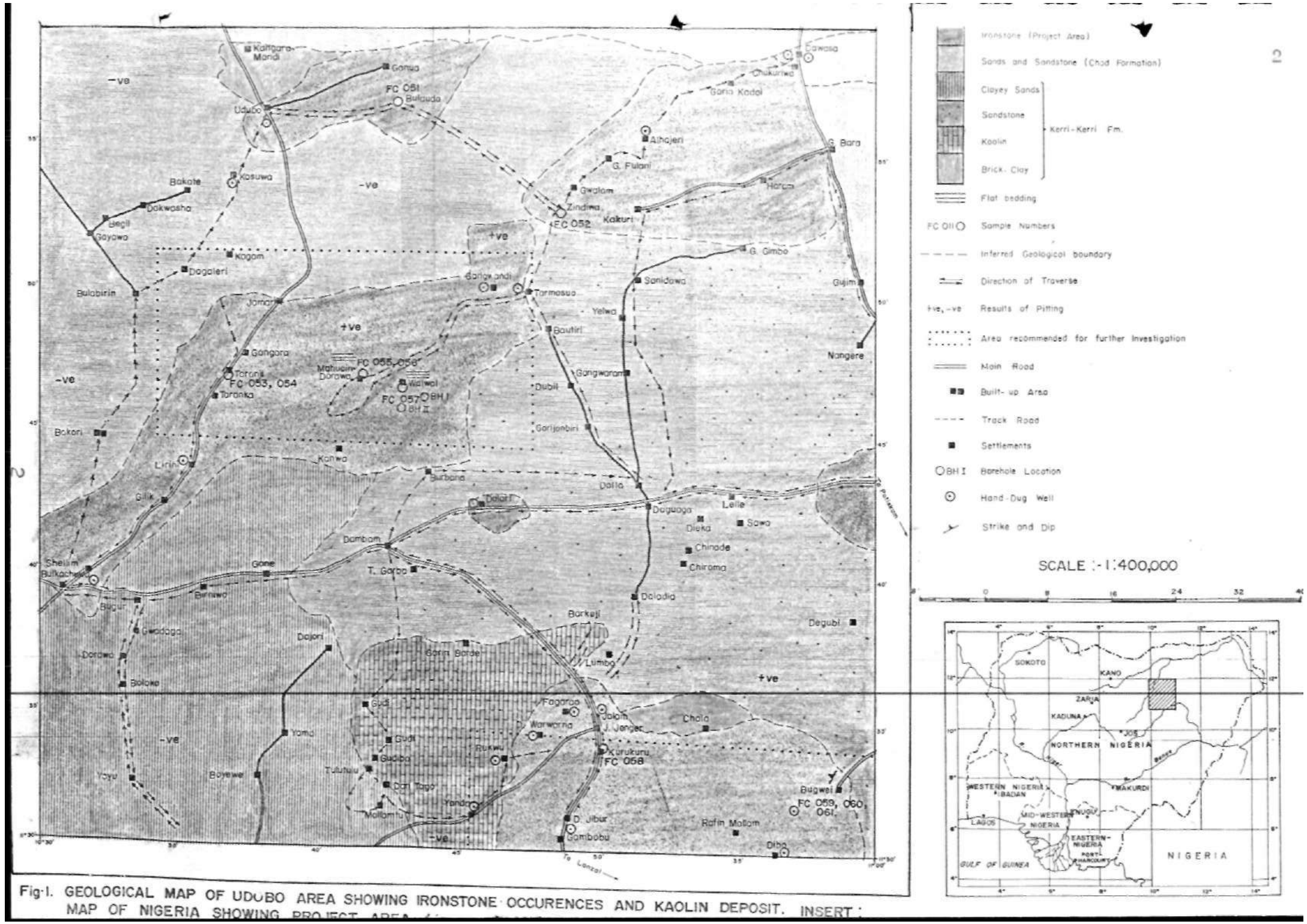
Taranji ironstone and Tumfure kaolin, lie within the central and southwestern portions of sheet 85 (Udubo). The sheet lies between longitudes 10° 30' and 11° 30'E and latitudes 11° 30' to 12° 00'N encompassing an area of 356 km^2 (Fig.1).

Tumfure is located along Dambam - Jalam road after Bulaudo well just before the forest reserve on the outskirt of Jalam. Taranji is located along Lirini - Taranka road. The quarry pit is about three hundred metres (300m) away from the major trunk 'A' road that runs from Bulkachuwa - Lirini - Udubo. The area of study falls within Gamawa, Dambam and Misau Local Government Areas of Bauchi State.

1.2 Relief and Drainage.

The topography is a gentle, flat and low-lying plain which slopes gently towards Lake Chad. Outcrops are scarce as topsoil masks the rocks rendering the area very flat. In the extreme southeastern tip of the sheet, prominent low flat-topped hills (mesas) occur. The sandstone/ironstone rise approximately 4-6 metres above the surrounding plain.

The important river in this area is River Diya. It is perennial. Tributaries such as Rivers Walwal and Maluein Dorowa are seasonal. They drain into River Diya which flows within broad valley, in dendritic drainage pattern in northeasterly direction towards Lake Chad.



Fig·1. GEOLOGICAL MAP OF UDUBO AREA SHOWING IRONSTONE OCCURENCES AND KAOLIN DEPOSIT. INSERT : MAP OF NIGERIA SHOWING PROJECT AREA

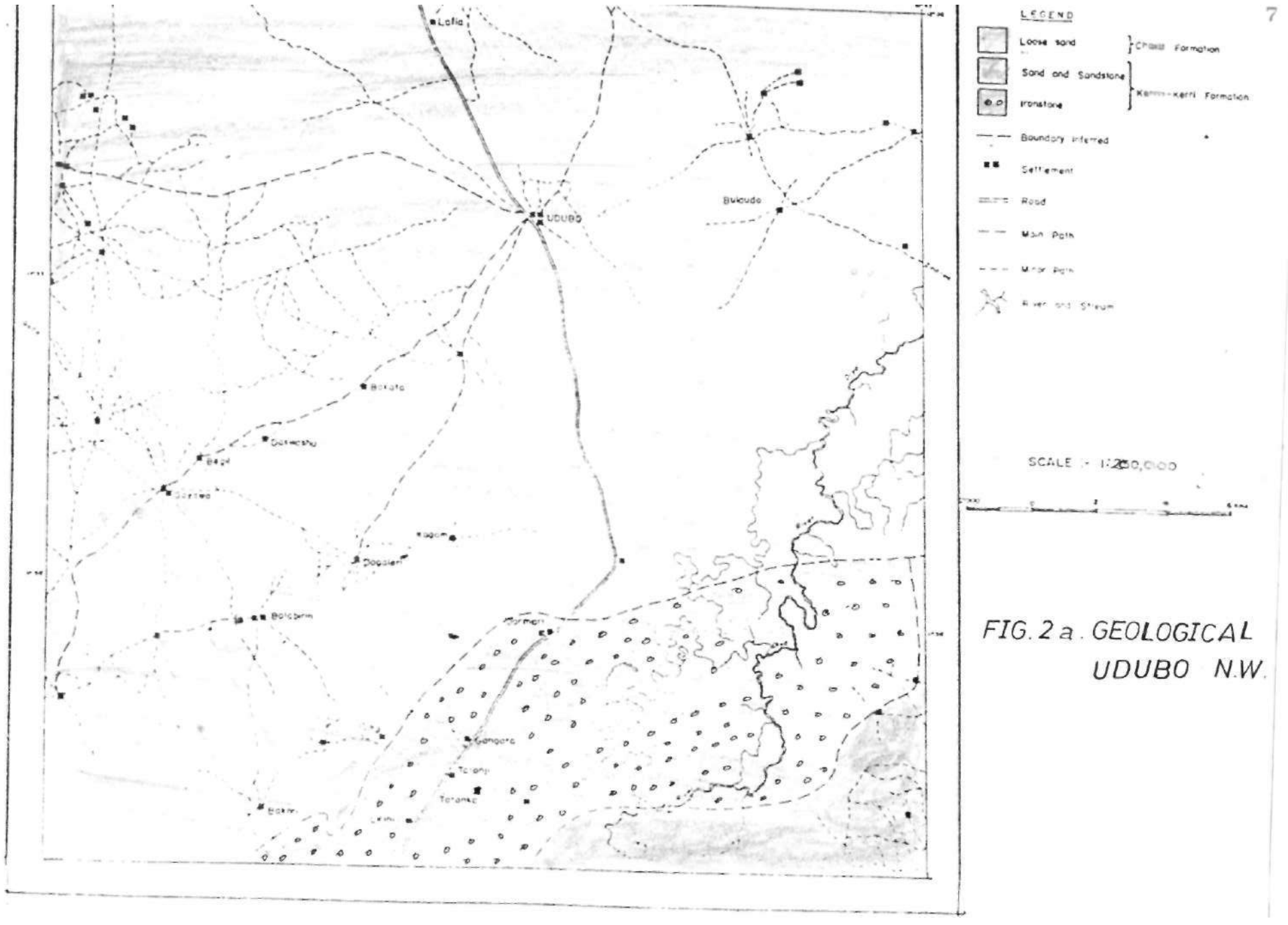
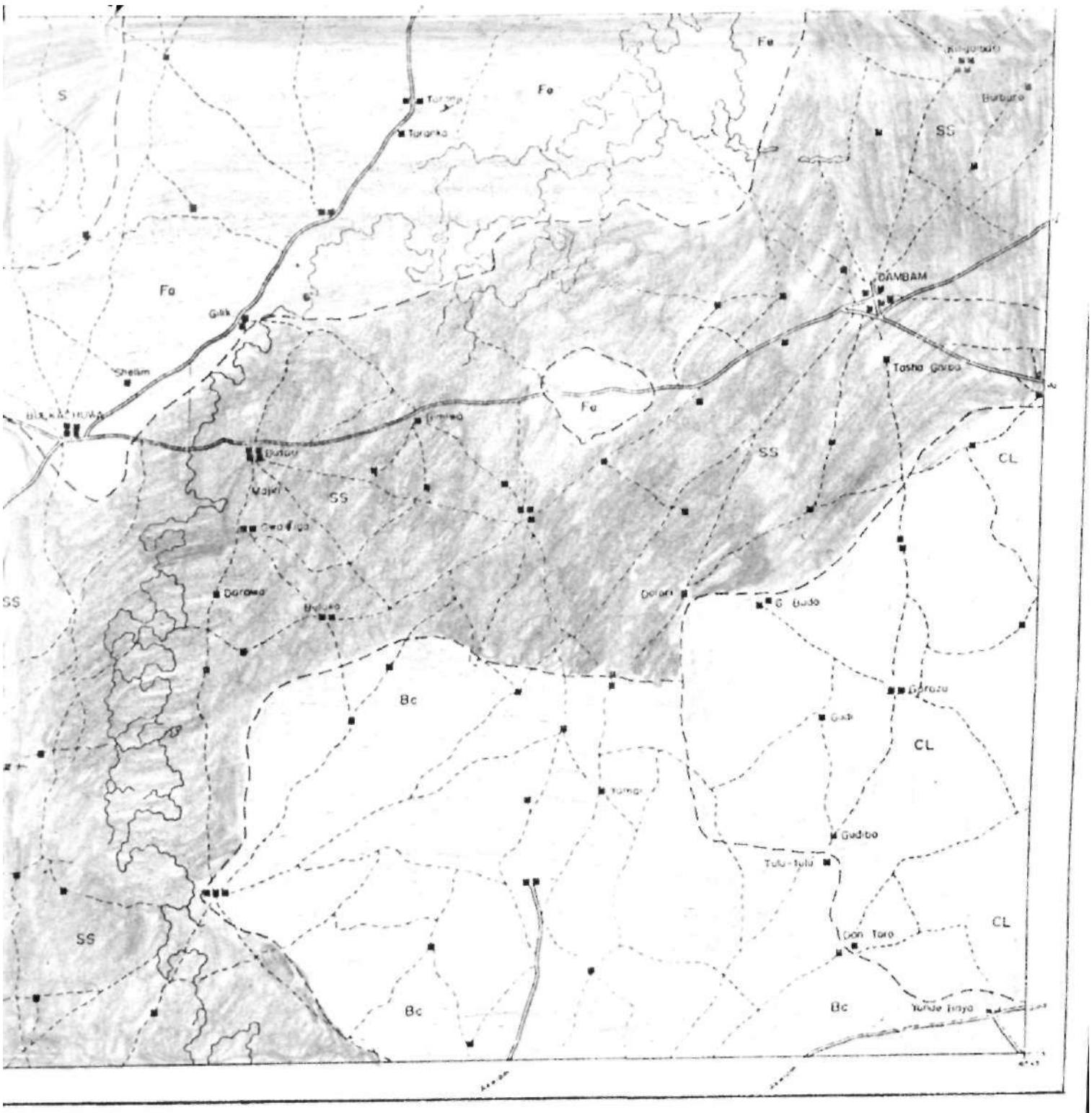


FIG. 2 a. GEOLOGICAL
UDUBO N.W.



SCALE - 1:100,000

LEGEND

- S — Loose sands / sandstone — Chad Formation
- SS — Sand / Sandstone — Kerri-Kerri Formation
- Fe — Ironstone
- Bc — Brick clay
- CL — Kaolin
- Geological Boundary
- Major footpath
- Minor footpath
- Settlements
- River
- Road
- Strike and Dip

FIG. 2B. GEOLOGICAL MAP OF UDUBO SW.

1.3 Climate and Vegetation.

The climate is tropical. Weather conditions are harsh, being very hot and dry with a fairly wide seasonal and diurnal range in temperature (65°C - 90°C) during the day and 45°C - 55°C at night. High temperatures predominates however especially at midday.

Period of rainy season is short. It lasts for less than four months between the months of June - August. The mean annual rainfall is about 15cm - 37cm. The long period of alternating wet and dry seasons results in fluctuation of ground water table that promotes intense chemical weathering, therefore, degradation of soils. Cold harmattan winds blow dry dusts and sands from November to March.

The vegetation is Sahel Savannah type, very open with few tree growth (Plate 1). The southern part is more forested than the northern parts. A more or less continuous cover of grasses, stunted trees with thorns, thick barks, scattered within the area during the rains but thick bushes occur in Bugwei area. In the dry season, the ground is bare .

Trees found in the area include Acacia albida, Africana Anogensis, Baobab isoberlina etc. Areas with ironstone contain clusters of shrubs with spikes signifying that the soil favours growth of drought resistant shrubs (Plate 2). This is useful in biogeochemical mapping.

1.4 Settlement and Land Use.

Settlements are preponderant in the southern part of the sheet than in the northern part. The southern part is more clayey than the central and the northern parts which contain ironstone on or close to the surface.

The land is used for farming and grazing. Places with clay or sandstone cover are intensely cultivated than areas with ironstone cover, which are usually bare, dry and may contain hard lateritic cover on the surface.

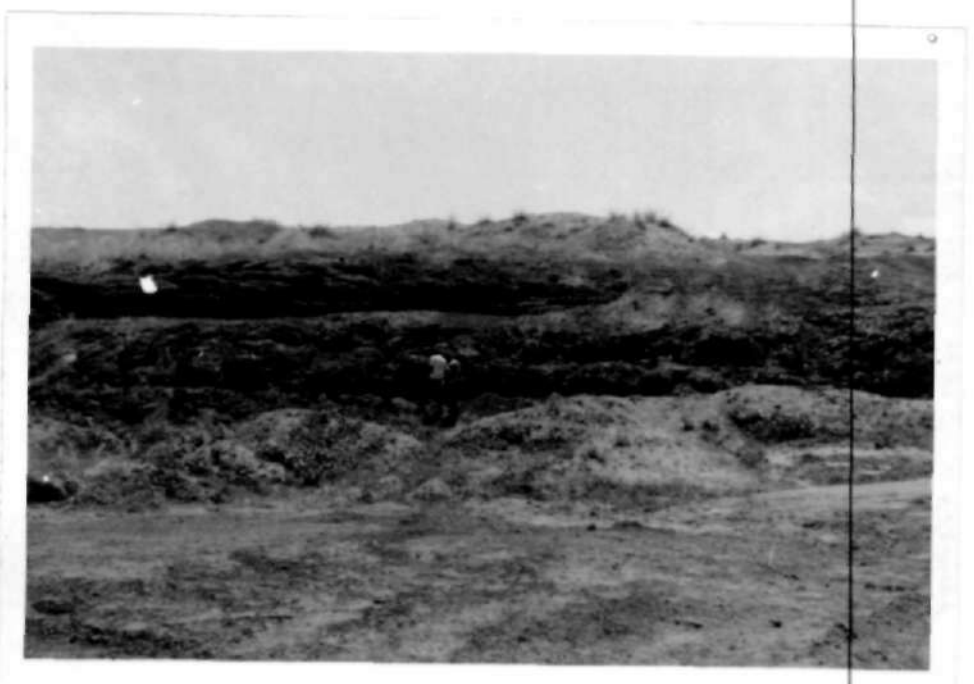


Plate 1: Area of Ironstone Occurrence Displaying Sahel Savannah Type of Vegetation at Taranji Quarry Pit.

The generalised sequence in this area from top to bottom is

Thickness	*Description*
0-0.5 m	*Loose, white unconsolidated sand*
0.5-2.0 m	*Oolitic ironstone*
2.0 m -	*Yellowish sandstone bottom not seen*



Plate 2: Thorny Trees On Bugwei Hills showing Sahel Savannah Vegetation.

1.5 Aim and Scope of Present Study.

The aims of this project work are to:

a. Produce the geological map of the area in 1:100,000 Sheet 85 (Udubo).

b. Highlight the occurrence of ironstone and kaolinitic clay in the area.

c. Determine the geotechnical and geochemical properties of the kaolin in a bid to promote its industrial use in ceramic and paper industry.

d. Determine the geochemical composition of the ironstone and relate it to use in steel industry.

e. Arouse more awareness for the mining of the ironstone in order to enable the inhabitants utilize the vast expanse of land containing the ironstone for agricultural cultivation purposes. The hard ironstone crust is difficult to cultivate.

f. The stratigraphy will assist hydrogeological investigations and development of the area.

1.6 Method of Study.

Reconnaissance Survey commenced in 1988, using topographic map of 1:100,000 Sheet 85 (Udubo) as base map. Detailed survey ensued afterwards, using maps of 1:50,000 Udubo NW, NE, SE and SW.

Instruments used included prismatic compass, hammer, hand-lens, and measuring tape etc. Random sampling was done initially, subsequently followed by the selection of representative samples for laboratory analysis, using the square grid of size 4 x 4 sq km as a guide. Samples were obtained from within the deposit locations and preserved in sample bags.

The yardstick for selection of representative samples included; the position of ironstone sample in the stratigraphic column - whether 'Lower' or 'Upper'; textural properties such as oolitic, pisolitic and massive texture and the purity of the ironstone, were all considered in the selection, therefore, each main body of ironstone had its representative samples analysed. Polished sections were prepared for mineralogical studies and with the aid of petrological microscope, composite minerals of the ironstone were identified. Wet chemical analysis method was used for oxide analysis at Geological Survey Department laboratory, Kaduna, while Atomic Absorption Spectrometre of the Institute of Agricultural Research, Ahmadu Bello University, Zaria, was used for elemental analysis and X-Ray Diffractometer at National Steel Council, Kaduna was used for mineralogical analysis and geotechnical analysis of the clay was done at Soil Science Laboratory, Ahmadu Bello University, Zaria.

In all, twenty-two (22) ironstone (AAS,WCA) samples were analyzed by wet chemical analysis method, while six (6) clay samples were analyzed by wet chemical, geotechnical (physical) analysis and X-Ray Diffractometry methods.

1.7 Previous Work.

Nnuka et al (1997) used wet chemical, sintering tests and spalling resistance etc methods in studying the clays at Ikot Igwe in Calabar area and characterized it as kaolin. He stated that beside Silica (SiO_2) and Alumina (Al_2O_3), clays contain oxides of iron (Fe_2O_3), titanium oxides (TiO_2) and alkali metal oxides ($CaO.k_2O$) and (Na_2O).

In applications where plasticity is required to be high as in ceramics, high alkali metal oxide content is required. However, for refractory application, high chemical purity and homogeneity, are the major demands on the clay, therefore, alkali metal content is low while alumina content is high in clays for refractory production (Nwajagu, 1987).

Refractory clay deposits occur in Sokoto area. The deposits at Giro, Kaoje etc are described as almost pure kaolin as it contains only kaolinite and 1% Fe.(Etu Efeotor, 1998). The Ibadan residual and Ozubulu sedimentary kaolin deposits in Oyo and Anambra States respectively, contain average kaolinite of 70% and 77% but they can be improved upon by beneficiation to 80 - 85% kaolinite to satisfy industrial requirements

Clay is used extensively in foundry, ceramics, building, chemical and electrical industries. They are used in glass making, cement, roof and floor tiles manufacture, porcelains, sanitary wares, refractory bricks and fillers for ladles and furnaces and abrasives. They possess high chemical stability, wear resistance, excellent thermal shock tolerance. Refractories are particularly used in high temperature processes especially between 1400°C and 2000°C. Kaolin is in great demand everywhere in the world as the best grades of deposits are becoming depleted in all kaolin producing countries (Fig. 6, Tables 1a, 1b). Many miners do not keep records of the amount of kaolin mined especially in developing countries.

Ironstone is any rock that contains great percentage of iron minerals such as haematite, limonite, goethite, turgite, siderite, chamosite and magnetite, but for an ironstone to be useful in iron and steel industry, it must contain 25 - 35% iron (Fe) <0.3% Sulphur and <0.4% Phosphorous (Whitten and Brooks, 1972).

Nigerian iron deposits were investigated by earlier workers such as Adekoya (1981), Mucke and Neuman (1980), Muotoh et al (1981), Adeleye and Dessauvagie (1972), but priority was given to Precambrian Iron Formation. Being a multiorigin deposit, ironstone is ubiquitous and widely distributed in rocks of different geological ages and conditions - the basement complex and sedimentary rocks. This led to proliferation of names such as 'ferruginous quartzites' or 'Banded Ironstone' or simply as 'Precambrian Ironstones', (Muotoh, 1973).

Adekoya (1981), distinguished between Banded Iron Formation and ironstone, that while Iron Formation is characteristically banded, chert-bearing with a high silica iron ratio (except where sulphide-rich), ironstone is unmetamorphosed, sedimentary, oolitic, pisolitic or massive and Phanerozoic in age. In Nigeria, Iron Formation occurs in Sokoto, Birni Gwari, Toto, while ironstone occurs in Bida, Lokoja, Agbaja, Enugu and Taranji (this work). The genesis propounded for Iron Formation in the schist belt is that it is of *the itabirite-type and metasedimentary in origin (Adekoya, 1981).*

Mucke and Neumann (1980), made further interesting deductions from mineralogical studies, that a combined magmatic and contact metamorphic processes culminated in the formation of Itakpe iron ore because the mineral association of primary magnetite which is rich in exsolution bodies such as ilmenite occurring with kaolinite plus relics of feldspar in the same paragenesis, correspond to typical intramagmatitic titanomagnetite-type deposits.

The ironstone of Bida basin was investigated by Adeleye and Dessauvagie (1972). They stated that Sakpe Ironsone in Bida and Lokoja areas; the Batati and Agbaja Ironstone occur as caps on mesas walls. They may be oolitic, pisolitic or massive in texture containing fossils like Ostrea, Turritela, Lopha which suggest shallow water agitated marine to freshwater condition of deposition during Campanian to Maestrichtian age. However, the ironstone contains much phosphorous 0.8 - 1.3% which renders it unsuitable for use in iron and steel industry. Ironstone is used as raw material in iron and steel industry to produce materials for doors, windows, burglary proofs, cars, utensils etc.

Turner (1971), referred to the Chad Basin of north-eastern Nigeria as comprising of grits and clays. Apart from mere mentioning of the occurrences, no work was done on the ironstone to determine its suitability for industrial use. The clay is yet to be mined too in this area.

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The project area being situated within the Chad Basin is surrounded by sediments of Chad Formation in the northern, western and eastern sides. In the southern part it is bordered by sediments of Kerri kerri Formation which directly ouverlies Palaeozoic basement complex. The neighbouring sheets to the eastern side is underlain by sediments of Upper Benue Trough with Albian-Cenomanian Bima sandstone overlying the Palaeozoic basement(Table 2). The Benue Trough was a zone of regional tectonism which controlled the break of Gondwana. It forms part of the Trans African lineament which runs through Niger, Libya and Egypt - a zone of crust weakness and megamineralization.

Table 1(a). **SUMMARY OF SOME RESIDUAL CLAY DEPOSITS IN NIGERIA**

Deposit Location	State	Type	Reserve in Tonnes
Ukpor	Anambra	Kaolinitic	6,000,000
Uzubulu	Anambra	Kaolinitic	4,200,000
Okpekpe	Bendel	Kaolinitic	6,000,000
Kankara	Katsina	Kaolinitic	3,400,000
Ifflo	Sokoto	Kaolinitic	Very large
Kaoje	Sokoto	Kaolinitic	Large
Giru	Sokoto	Kaolinitic	Large
Bamajo	Ogun	Kaolinitic	Large
Lishabi	Ogun	Kaolinitic	Large
Onibode	Ogun	Kaolinitic	Large
Ropp	Plateau	Kaolinitic	Not available
Dawakin Tofa	Kano	Kaolinitic	Not available
Garkida	Gongola	Kaolinitic	Not available
Biu	Borno	Kaolinitic	Not available
Trade	Oyo	Brickclay	1,524,000
Enugu	Anambra	Brickclay	19,000,000
Mararaba-Rido	Kaduna	Brickclay	5,524,000
Jos	Plateau	Brickclay	Large
Maiduguri	Borno	Brickclay	Large
Enugu	Anambra	Fireclay	50,000,000

(after Adamu and Timar, 1980)

Table 1(b)

KAOLIN PRODUCERS IN THE WORLD

Country	Types and Source rock	Reserves (Metric tons)	Production in thousand of metric tons	Main Usage	Remarks
USA	Residual, Hydrothermal Sedimentary Pegmatite and from applite veins	Over 1 billion	4,823	Paper coaster & Ceramics (Buie, 1972)	Potential Resources below the surface are greater than the estimated reserves.
U.K.	Residual, mainly Hydrothermal from alteration of granite		3,005	Paper coaster	Largest exporter
U.S.S.R	Residual, Hydrothermal and sedimentary	200 million	2,000	Paper coaster, ceramics, rubber and chemical industry	Best grades produced from deposits formed in weathered granites and gneiss
FRANCE	Primary and Secondary in origin from kaolinised granite Hydrothermal residual		525	Ceramics, filler for paper, points and rubber.	It imports from England and USA to its requirements
SPAIN	Primary and Secondary, from Hydrothermal alteration of mylonitized granite.	1 billion	513	Ceramic, often beneficiated for use in paper, paint, rubber and other industries	Fourth largest producer in Western Europe
F.R.G.	Sedimentary in origin		4.17	Ceramic Industry	
CZECHOSLOVAKIA	Primary	1 billion	1,000	Ceramic, paper, rubber and refractories	Principal producer in Eastern Europe
CHINA	Residual from deeply weathered granite	Deposits used first in China	Production not verified	Ceramic for manufacture of fine Chinaware	It has 70% pure kaolin and still being mined on large scale

** SPAIN	Primary and Secondary, from Hydrothermal alteration of mylonitized granite	1 ** billion	513	Ceramic, often beneficiated for use in paper, paint rubber and other industries.	Fourth largest producer in Western Europe
F.R.G.	Sedimentary in origin		4.17	Ceramic Industry	
CZECHOS-LOVAKIA	Primary	1 billion	1,000	Ceramic, paper rubber and refractories	Principal producer in Eastern Europe
CHINA	Residual from deeply weathered granite	Deposits used first in China	Production not verfied	Ceramic for manufacture of fine Chinaware	It has 70% pure kaolin. and still being mined on large scale

(after Adamu & Tim ar, 1980)

CHAPTER TWO

GENERAL GEOLOGY

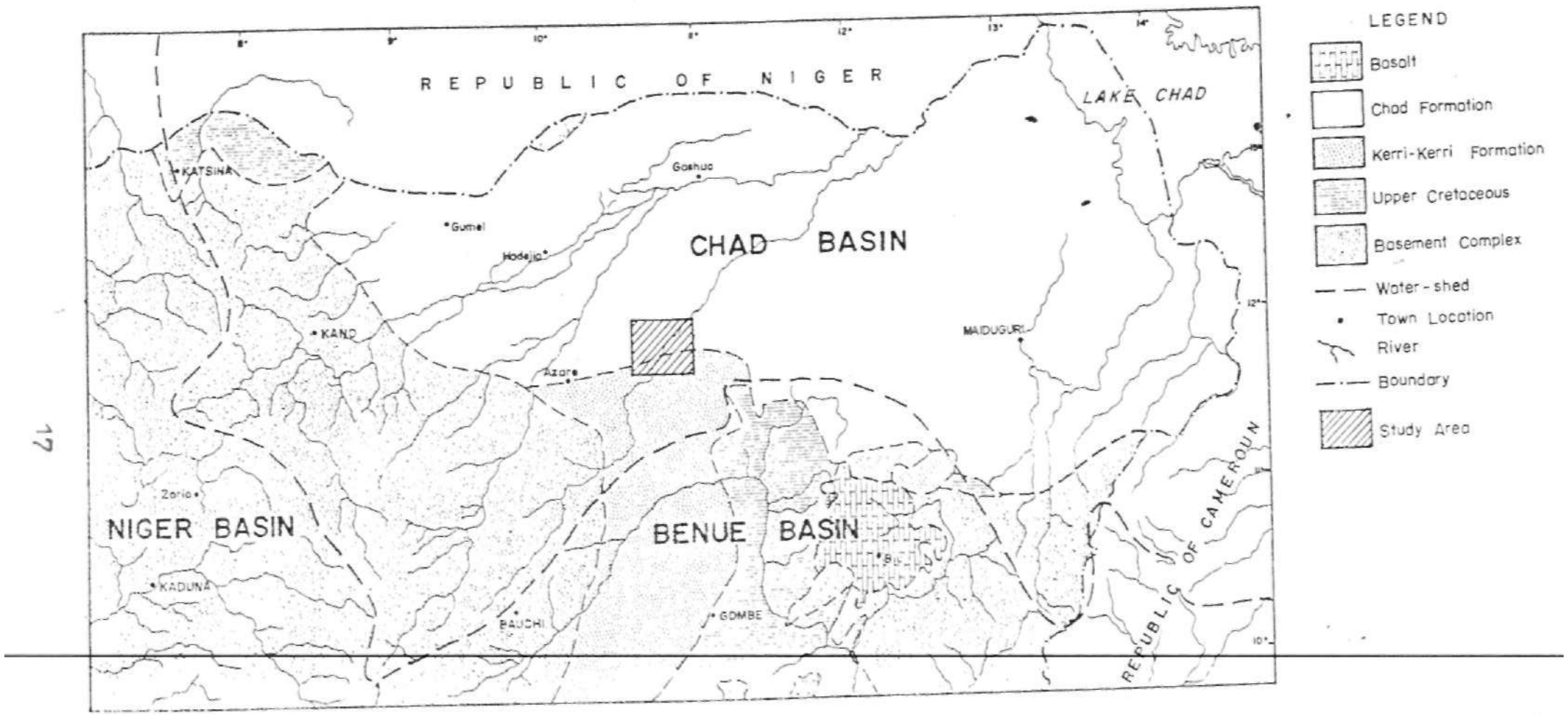
2.1 Introduction:

The sedimentary sequence in the Chad Basin consists of clays, ironstone and sandstone of Cretaceous age, which may be more than seven hundred metres (700 m) thick (Barber, 1965). The beds are generally low-lying, flat-lying and slopes gently northeastwards. In the southeastern tip of the sheet, folded sandstone and ironstone form series of 'great' anticlines and synclines (Barber, 1965) (Plate 2). The hills are capped by extensive hard laterite derived from the weathering of the underlying rocks.

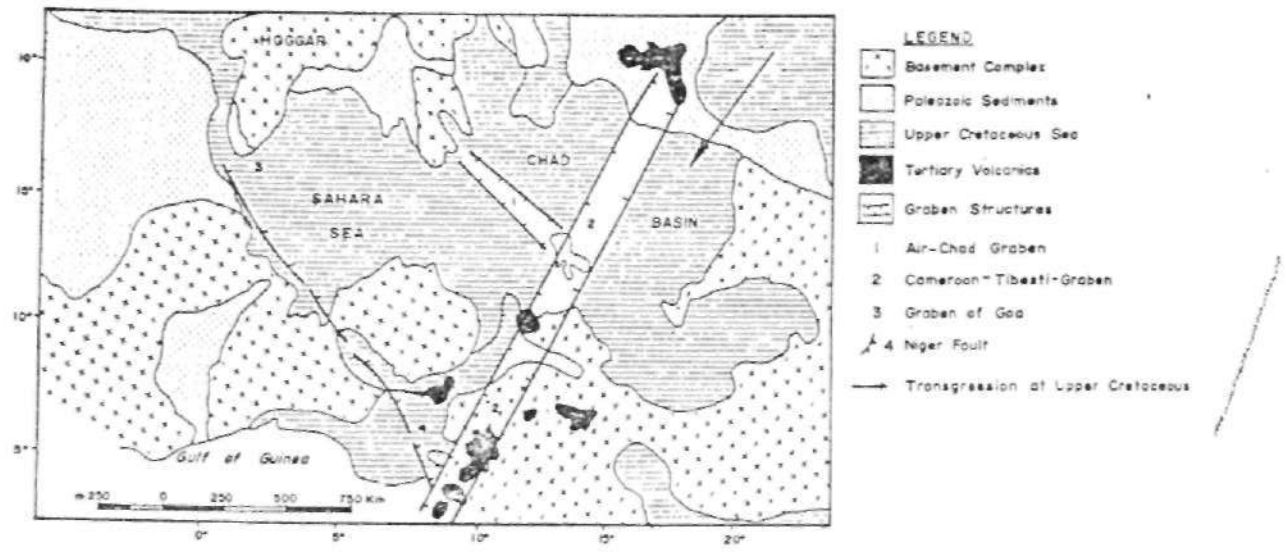
Eight (8) lithostratigraphic units recognized in the map area in ascending order are:- clay, 'lower' ironstone, yellowish sandstone, greyish sandstone, 'upper' ironstone and unconsolidated sand. The clay, 'Lower' ironstone, yellowish sandstone, greyish sandstone and 'upper ironstone' belong to Kerri Kerri Formation, which is Palaeocene in age based on palynomorph studies. The unconsolidated sand belongs to the Chad Formation. It is exposed in the extreme northwestern part of the sheet around Begil, Dakwasha and Bulabirin villages (Fig. 1). Chad Formation is Quarternary in age, based on dating of diatoms (Barber and Jones, 1966).

2.2 Regional Setting

The Chad basin is a structurally depressed zone, which serves as the largest inland drainage occupying an area of approximately 230,000 km^2. Furon (1963), believed it was a tectonic cross-point between a northwest to southeast trending Air - Chad trough while the other extends northwest, from beneath Lake Chad to underlie the Temere rift structure bordering the eastern side of the Air Massif (Figs. 3 and 4).



Fig·3. Map showing the geology and extent of the Chad Basin in Nigeria (GSN).



Fig·4. Geological framework of the Chad Basin. (After, Barber & Jones, 1963)

The depression created by the trough, provides harbour for accumulation of thick pile of sediments in the Palaeocene-Tertiary. Continental sediments of Kerri-Kerri Formation was deposited in the southwestern portion of the basin in the Palaeocene while lacustrine sediments of Chad Formation was deposited in the northwestern part in the Pleistocene-Pliocene period (Table 2). The Chad Basin trough possesses northeast to southwest trends similar to the structures in the Benue valley. This made Furon (1963) to suggest that the Chad Basin was created by rifting and faulting.

Kerri Kerri formation lies unconformably over early Palaeozoic Basement Complex. This relationship is exposed at Rivers Biyalli, near Maina Maji in Bauchi State which prompted Dike and Egbuniwe, (1994) to state that this relationship is an unconformity instead of a faulted one proposed by Adegoke et.al, 1986. Adegoke (1988), suggested that the faulting was synchronous with deposition and acted as a hinge line. Boreholes record from Alkaleri, Darazo, Kwankiya, Misau, Chinade, Giade, Azare and (this work) at Walwal, supports Dike's view as Kerri Kerri overlies the Basement Complex directly, in all these places.

Dike (1992), further stated that the sediments of Kerri Kerri Formation were believed to have been deposited in alluvial fluvial environments. Elsewhere, marginal lacustrine and deltaic environments were suggested by Carter et.al (1963), for the Kerri Kerri Formation. However, the rapid facies changes with braided fluvial coarse sandstones, passing laterally into channel fill deposits coupled with the formation of unconformably overlying eroded Late Cretaceous rocks - namely the Gombe sandstone and Fika shale in central part and eastern margin of its outcrop area, (Carter et. al. (1963), suggest non-conformity (Fig. 5).

Palaeocene age was given to Kerri Kerri Formation because it lies unconformably over Palaeozoic Basement rocks (Fig. 6). Pleistocene age was suggested for Chad.

Table 2 **STRATIGRAPHIC SEQUENCE IN THE CHAD BASIN OF N.E. NIGERIA.**

Age	Formation	Environment
Pleistocene	Chad Formation (Unconformity)	Lacustrine Strata
Palaeocene	Kerri-Kerri Formation (Unconformity)	Continental Strata
Maestrichtian	Gombe Sandstone	Estuarine delta
Senonian	Fika Shales	Marine Strata
Turonian	Gongila Formation	Marine estuarine Strata
Cehomanian	Bima Sandstone	Continental Strata
Pre-cehomanian	Basement Complex	

(After Matheis, G. 1975)

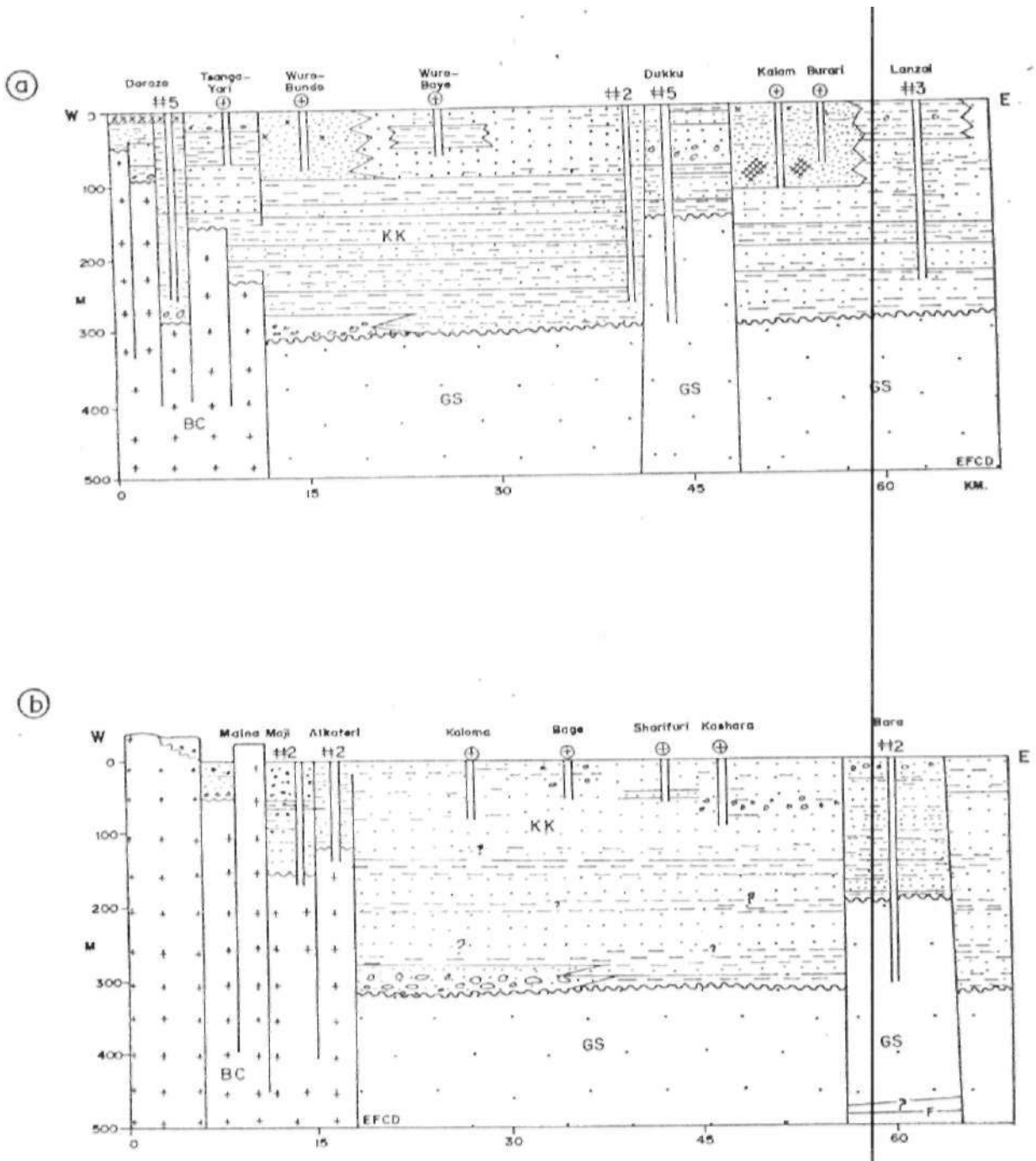
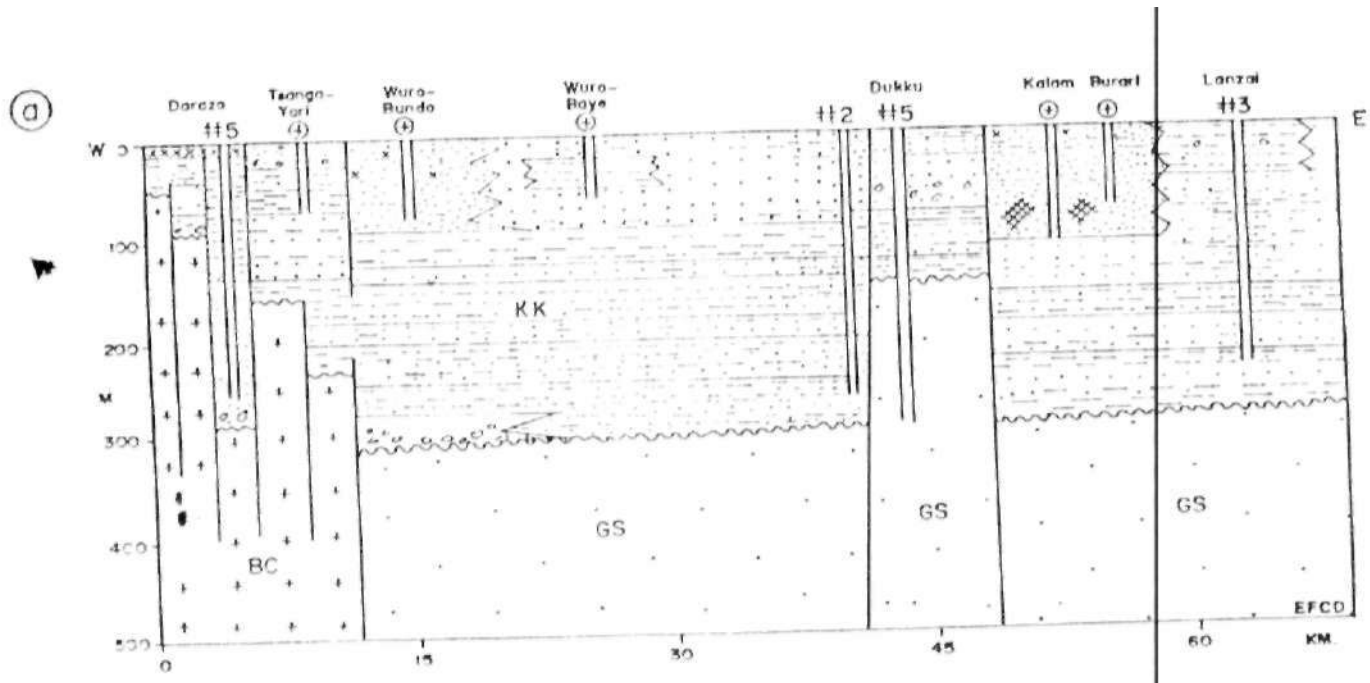


Fig 5. Idealized stratigraphic and some structural relationships in part of Kerri-Kerri across the western margin (after Dike, 1992).

a) Northern part : Localities from Darazo-Lanzai.
b) Southern part : Localities from Maina-Maji Bara.



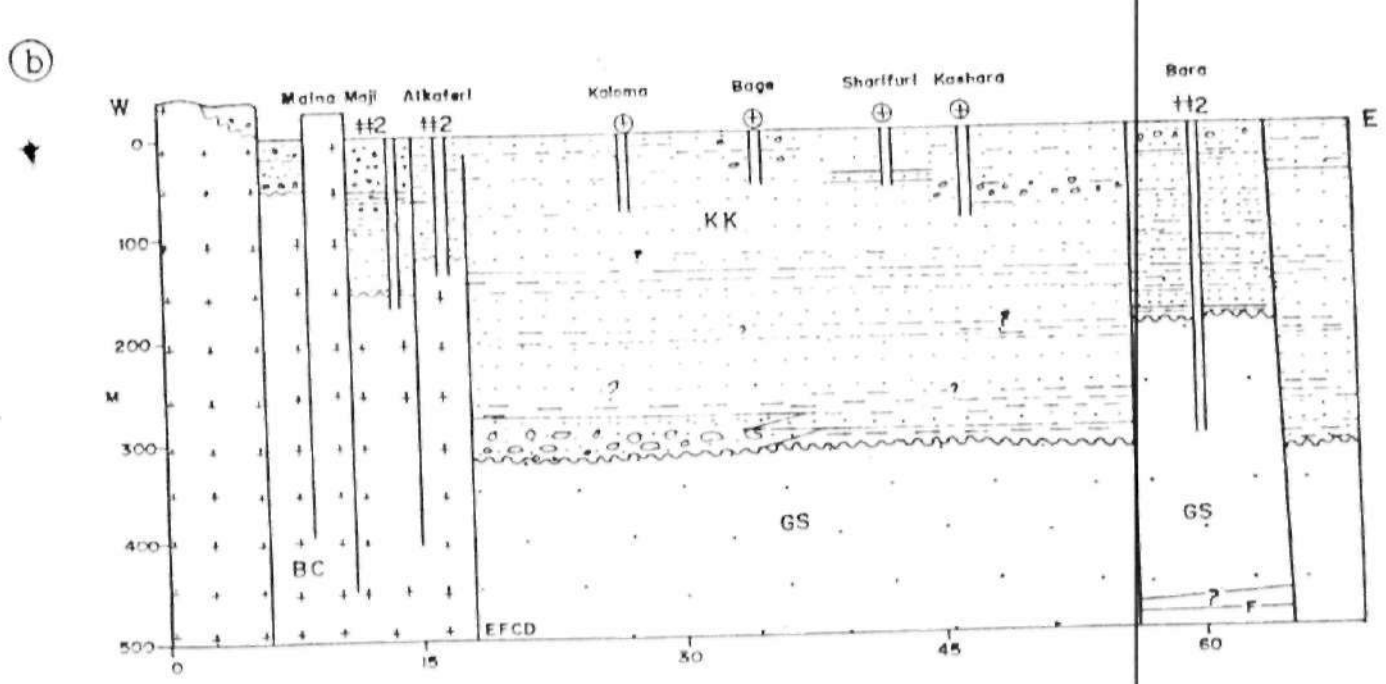
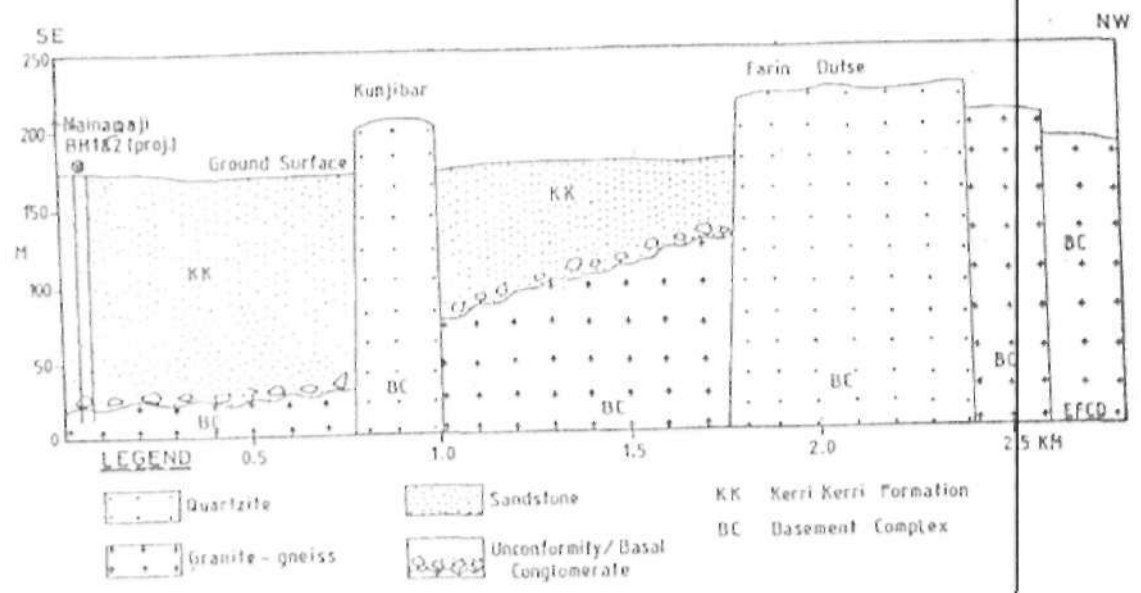


Fig 6. Idealized stratigraphic and some structural relationships in part of Kerri-Kerri across the western margin (after Dike, 1992).

a) Northern part : Localities from Darazo-Lanzai.
b) Southern part : Localities from Maina-Maji Bara.



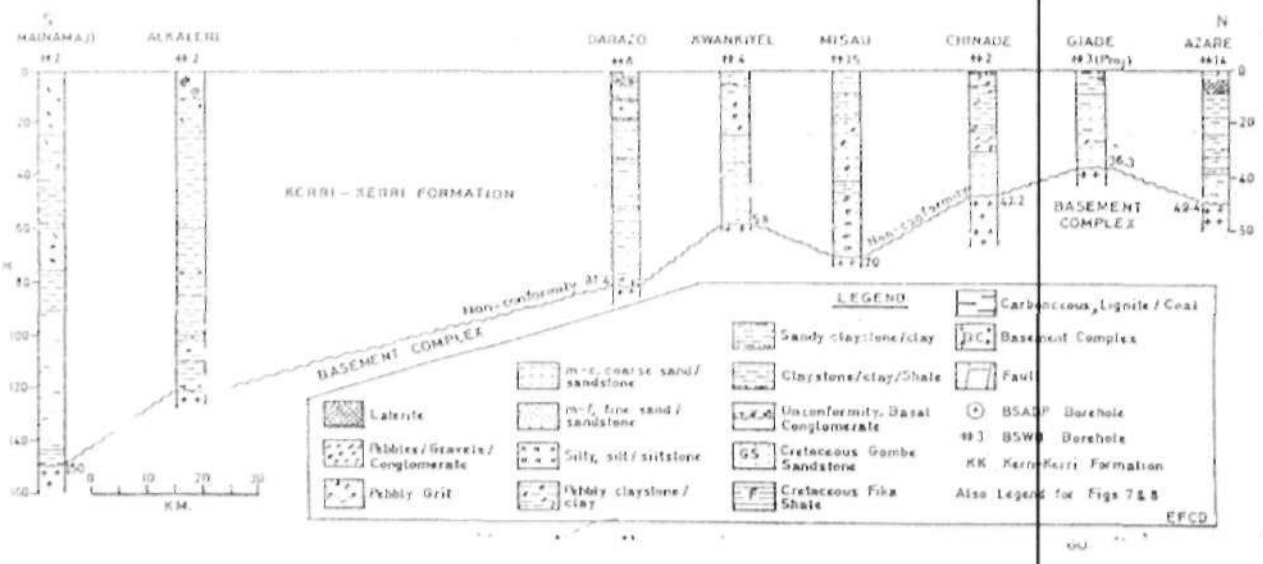


Fig 6. Idealized stratigraphic and some structural relationships in part of Kerri-Kerri across the western margin (after Dike, 1992).

Formation, based on the dating of vertebrata remains - immangulate diatoms. Some sediments however occur below the dated strata, therefore, Matheis (1975), proposed that the age commenced from the Pliocene.

CHAPTER THREE

3.0 FIELD GEOLOGY AND PETROLOGY

Geological mapping indicates that the area is underlain by lithological units of both the basement complex and sedimentary rocks. The three major lithological units in the area are, namely;- the Basement Complex, Kerri kerri Formation and Chad Formation (Figs. 1and 2).

3.1 The Basement Complex.

Coarse Porphyritic granite was found at Bugwei at its contact with yellowish sandstone. It is directly overlain by yellowish sandstone here. Medium - grained Older Granite was also struck at a depth of 48.8m and 38.8m in boreholes No.1 and 2 drilled for ironstone in Walwal area by the Geological Survey of Nigeria.

3.2 Kerri Kerri Formation.

Sandstone and clays of Kerri kerri Formation cover the southern part of the sheet extending from Yayu area in the extreme southwest to Bugwei in the southeastern part of the sheet. It extends northwards to Alkaleri area in the northeastern part of the sheet and covers about three-fifth of the sheet. In the southeast, it forms boundary with Gombe sandstone, while in the southwest it is bounded by the basement complex.

Outcrops are scarce and few with only exposures encountered in most places, due to weathering and erosion of the soft rocks. At Walwal, extensive, resistant compact, flat hardpan of ironstone cover the surface for more than three kilometres (3 km).

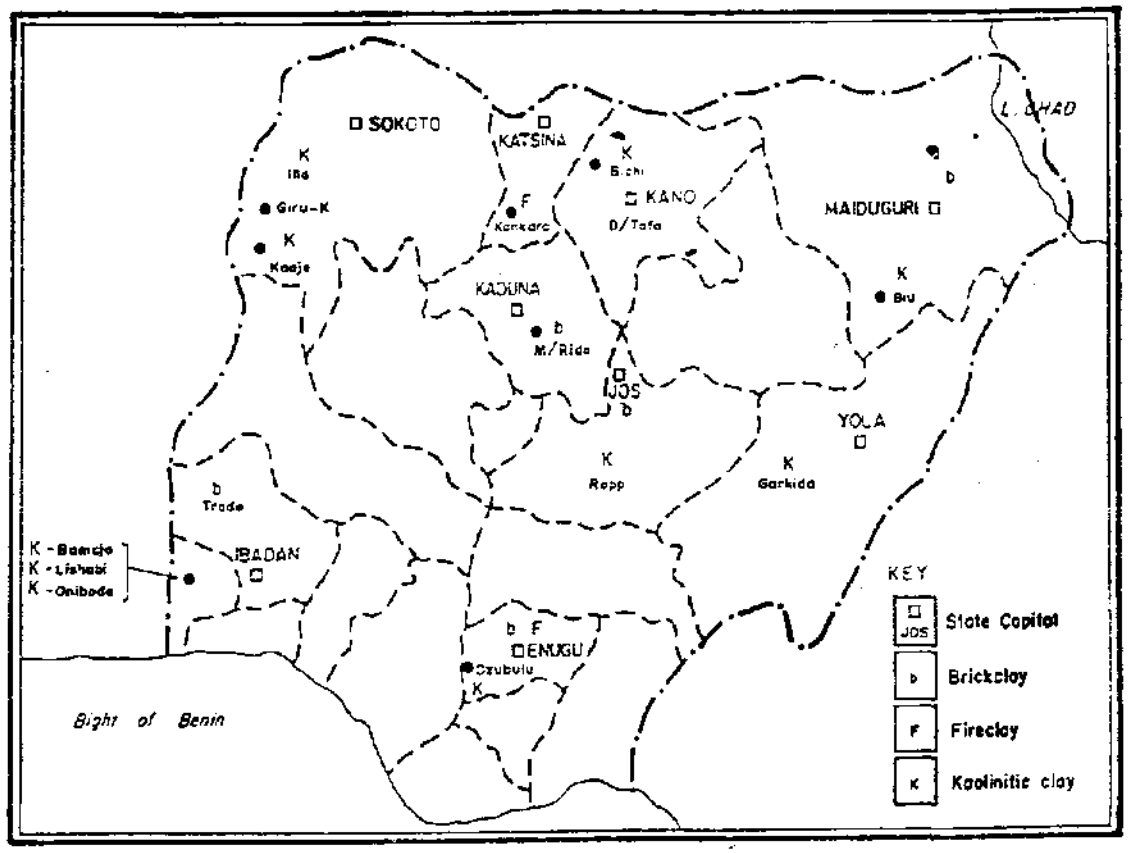


Fig 7. Sketch map of Nigeria showing areas found to have residual clay deposits. (After Adamu & Timar, 1980)



Plate 3: **Contact Between Yellowish Sandstone And Clay At Bugwei**



Plate 4: Yellowish sandstone overlying lower ironstone at Taranji

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Plate 5: Outcrop of 'Lower' Ironstone At Garigwandi Quarry Pit..

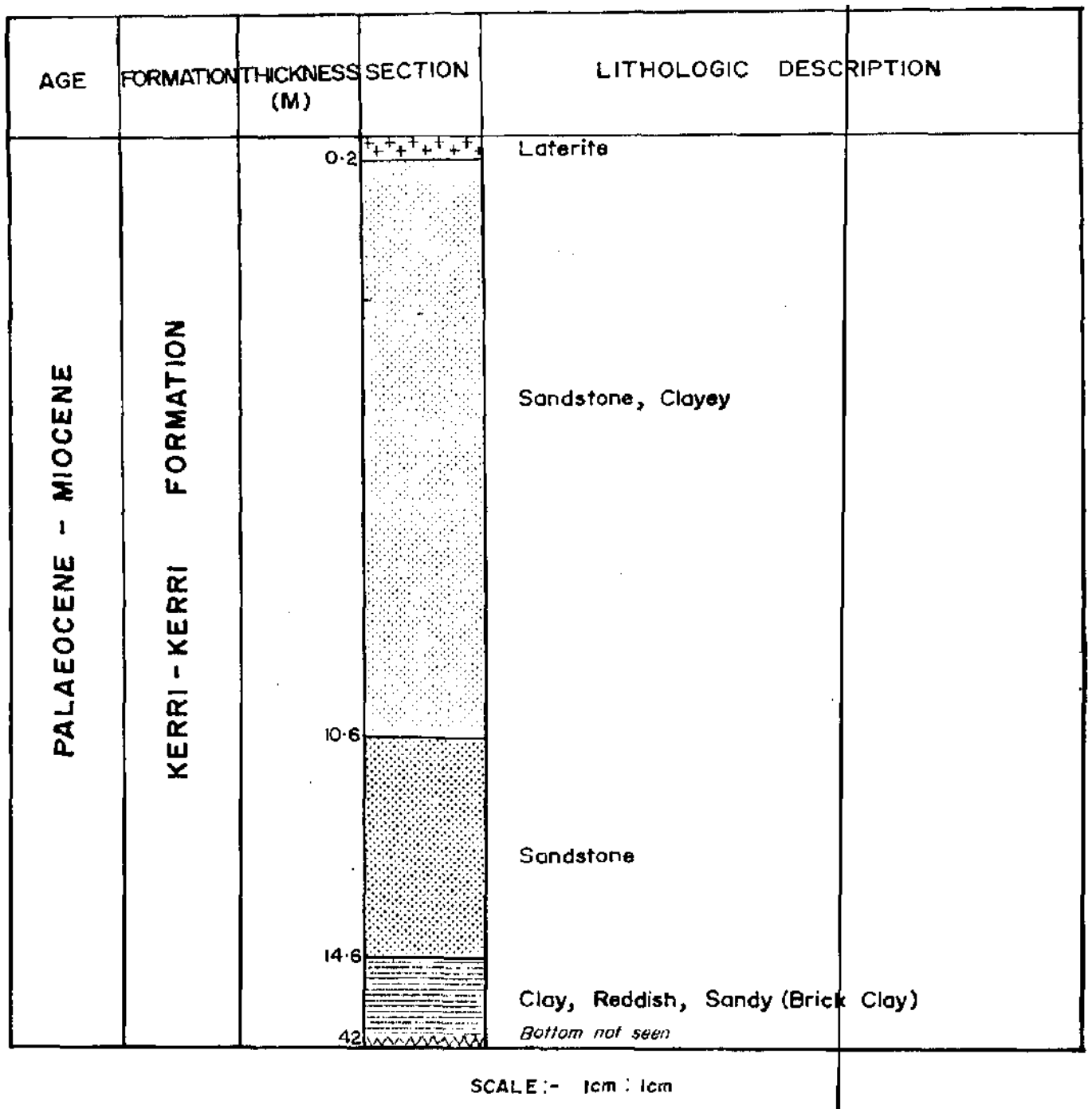


Fig. 8·a. Well section of Kerri-Kerri Formation at Yayu(clay arec

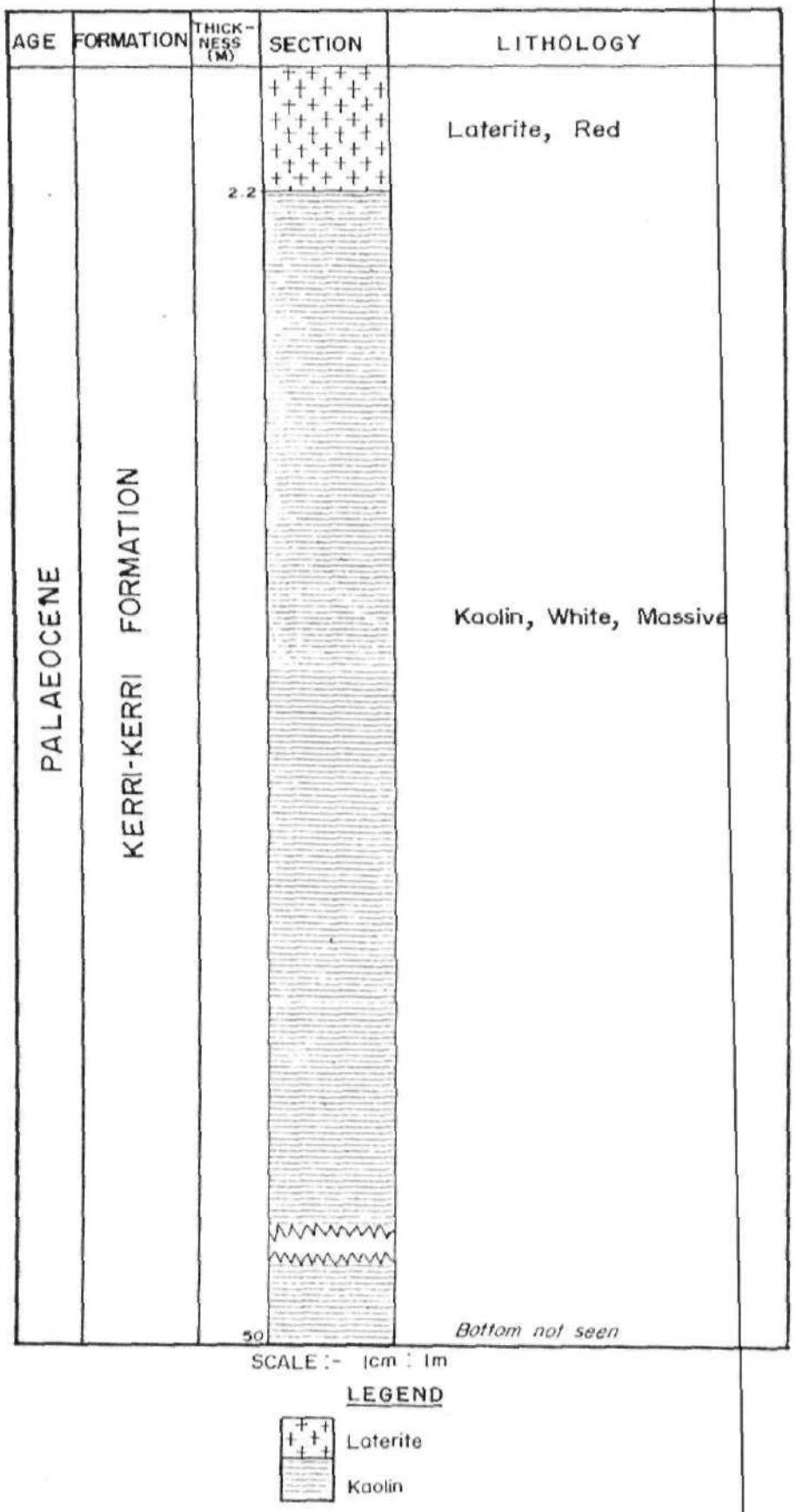


Fig. 8b. Well-Section of Kerri-Kerri Formation at Tumfure (Clayey Area).

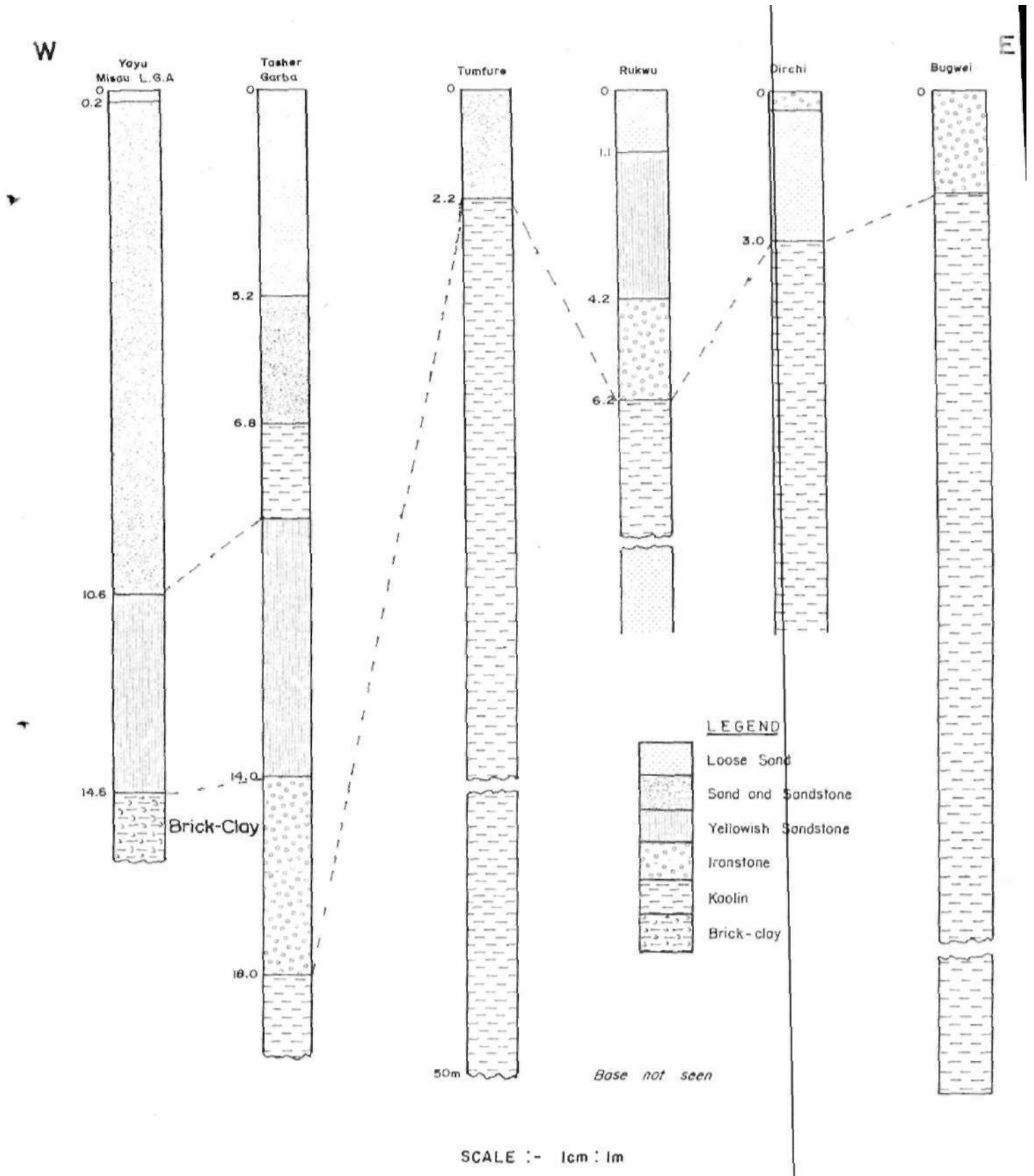


Fig. 8 Composite Well-Section across Southern part of sheet 85 Cla
Area (Udubo) Formation is Kerri-Kerri Formation (West - East).

c) **The Yellowish Sandstone**

The yellowish Sandstone overlies the lower ironstone directly. It is exposed at Taranji, R. Mahucin Dorowa, Bugwei etc. It can be observed in several wells in the area such as Wakili, Zindiwa, Udubo, Garigwandi, Dalari etc.

It is yellowish in colour, fine-grained, compact, or indurated and contains black rounded grains of goethite in some places e.g at Walwal (Plates 3-5).

d) **The Greyish Sandstone**

The greyish sandstone overlies the yellowish sandstone. It is medium to coarse-grained, slightly consolidated, clayey and gritty. It is well exposed at the valleys of River Diyanear Udubo, along Udubo-Zindiwa road. There it is more than four metres (4 m) thick.

e) **The 'Upper' Ironstone.**

This is a laterite It contains limonite and much quartz. It is reddish-brown in colour, gritty, porous, light in weight and commonly shows brownish badly formed oolites. Few cross laminations were observed in iron stone at kurukuru (Plates 6 & 7) 'Upper ironstone at Yanda and Dalari (Fig. 1). This implies that the direction of flow of transporting agents was constant most of the time.

3.3 Chad Formation.

The third formation in the project area is the Chad Formation which comprises of loose sand as its main rock type. Pockets of clay occur but they are too small to appear as mappable unit on the geological map.

a) Loose Sand.

Loose, unconsolidated fine-grained sand is the main lithological unit of Chad Formation. It occupies the northwestern part of the sheet and extends from Kasuwa to Begil-Gayawa to Bulabirin, Dakwasha etc. It covers great expanse of the land surface, except in few places, where it is interspersed by pockets of clay. It is about twenty-four metres (24 m) thick at Dakwasha.

3.4 The clay and Ironstone Deposits

3.4.1 Kaolinitic Clay I, Tumfure

Tumfure kaolinitic clay deposit is one of the best known sedimentary clay in northern Nigeria. It does not outcrop on the surface but extends in the subsurface to Rukwu, Barkeji, Gafa, Daladio, Fagarao, Garin Barde represented as locations I, II, III,



Plate 6: Outcrop Of 'Upper' Ironstone At Yanda.



Plate 7. Yellowish Sandstone, Underlying Ironstone At Taranji.

etc on the map. Tumfure is located approximately on longitude 10° 48' and latitude 11° 36' (Fig. 1).

The clay is excavated by the inhabitants usually during the wet season, when digging or reactivating wells. Wells hardly collapse because the ground is hard and rocks indurated. Stepwise pitting method is employed in the digging of wells, which may or may not be inclined to the surface. Surface/field evidence of clay occurrence is that the colour of the topsoil is remarkably lighter (whiter), in area of occurrence of the clay in contrast to adjacent neighbourhood, as exhibited at the Forest Reserve between Jalam and Bulaudo (Plate 2).

Evidence of the origin of the clay abound in the remnants of quartz grains which underlie it at Rukwu - very white silica sand deposit, suitable for glass manufacturing. It was derived from the underlying weathered medium-grained granite, transported and deposited, therefore, sedimentary in origin, however, no bedding or lamination was observed within the clay in the area of study. The well-section at Garin-Jaji, some twenty-four kilometres (24km) from Bulkachuwa along Bulkachuwa-Misau road, where weathered kaolinized granite directly underlies the clay, shows feldspars weathering into kaolin (Plate 3).

The clay is massive, pure white in colour. It is smooth, soft to touch and consists of 58 - 94% <2 microns particle size which qualifies them as a very fine-grained earthly substance. Both brickclay and kaolin occur. At Yayu and Bugwei the brickclay is over 40 m and 250 m thick respectively (Fig. 8).

Overburden consists of sand and ironstone. It masks the clay and varies in thickness from 0.1m to 24m. At Tumfure it consists of lateritized sandstone, less than 2 m thick. The contact between the clay and the underlying whitish glass-sand is exposed at Rukwu, in a well.

The clay is used by the inhabitants for painting their houses. The areal extent of kaolin is

112 km^2 and average thickness is 26 m. The tonnage is estimated at over twenty-five thousand tonnes (25,000 metric tons).

3.4.2 **Kaolinitic Clay II, Tashar Garba**

This deposit is located some two kilometres to Dambam market at Tashar Garba primary school along Jalam - Dambam road while Tashar Garba is located on longitude10° 44' and latitude 11° 40' approximately.

The deposit was well - observed in a hand-dug well, in front of the village primary school where it attains thickness of about 3.2 m and falls between 6m - 9.5m depth at this location. The stratigraphy reveals that this layer of kaolin is different and higher than the one at Tumfure. It is directly overlain by yellowish compact sandstone while Tumfure kaolin is overlain by the 'Lower' Ironstone (Fig. 7). The clay is massive, milky white or cream yellow in colour, lighter in weight and comprises 68% kaolin and free quartz. See result of wet chemical analysis of clay (Table 3).

3.4.3 **Ironstone 1: Taranji Area**

Taranji ironstone is located in the northcentral part of the sheet (Fig. 1). It includes the ironstone of Taranka, Udubo, Zindiwa, Tarmasua, Walwal, Alkaleri areas, all localities in the northcentral and northeastern part of the sheet. The area is between longitudes 10° 30' - 10° 47' and latitudes 11° 39' - 11° 52'. Taranji is located on longitude 10° 36' and latitude 11° 48' (Fig. 1), Plates 1, 4 & 5).

Vertical profiles can be observed at Taranji quarry pit where the ironstone is exposed by the activities of Roads (Nig) Ltd, a road construction company that quarried the ironstone for road construction. The deposit is coffee - brown or reddish - brown in

colour, oolitic or pisolitic in texture and vary in thickness from place to place. Thickness range from mere exposures, as at Taranka to >28 m at Garigwandi (Fig.8d).

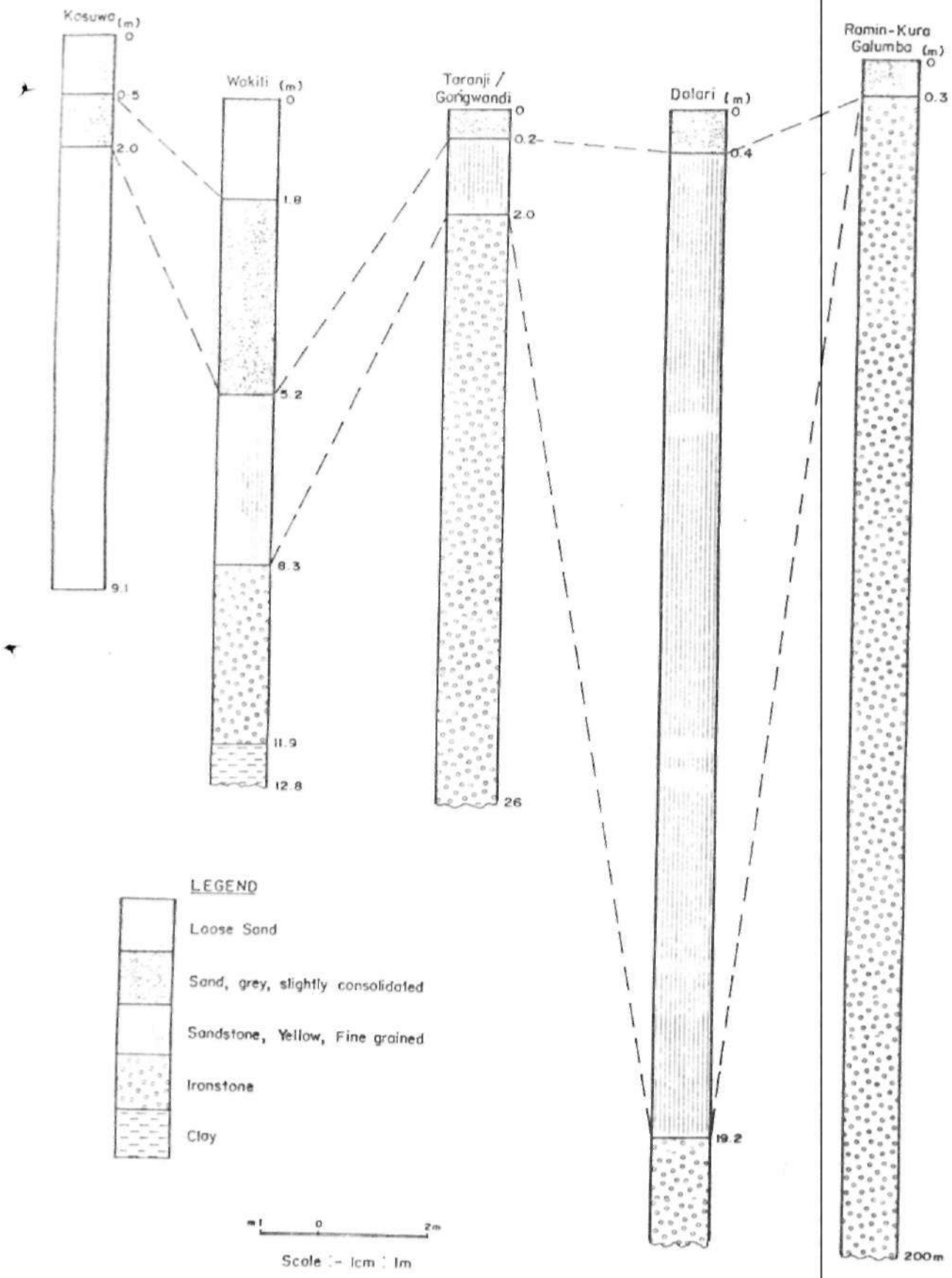
It is overlain by loose sands which vary in thickness from<2 m at Taranji to >12 m at Wakili to >16 m at Ududo. Directly below it is yellowish fine to coarse - grained vesicular sandstone.

Hand specimens are indurated, compact, heavy and contains higher percentage of iron content and less quartz grains than those from the southern part of the sheet i.e. Bugwei area. At Taranji and Walwal, chemical analysis gave a result of 56% Fe_2O_3 and >2% Fe_2O_3 respectively, for the ironstone (Table 6). Oolites are preponderant over pisolites at Taranji, while big pisolites predominates along the valley of River Diya, near Walwal. The ironstone is sedimentary in origin due to the presence of cross - bedding.

3.4.4 Ironstone II: Bugwei Area

The ironstone in this area includes those of Bulaudo, Dalari, Jalam, Yanda, Kukuruku, Dibon, Rafin Mallam, Ramin kura, Bugwei etc. - all localities in the south eastern quarter of the sheet. The area is bounded by longitude 10^0 47' - 10^0 59'E and latitude 11^0 30' to 11^0 37'N. Bugwei is located on longitude 10^0 59' and latitude 11^0 37'. Bugwei hills is directly opposite Kukar Primary School along Lanzai - Potiskum road.

The ironstone is reddish - brown in colour, may be oolitic, pisolitic or massive in texture, very gritty and contains abundant angular quartz grains. Exposures are available at Garin Mallam, Yanda, Dalari, (Plates 8 & 9) but the greater part of the deposit occur in the subsurface, for example at Ramin kura and Dibon the ironstone is about twenty metres (20 m) and fifly metres (50 m) thick respectively (Plates 6 & 8). Overburden comprises of sandstone and loose sands, which range in thickness from 1m e.g at Dalari to more than twenty-six metres (>26m) at Daladio. It is underlain by yellowish sandstone



Fig·8d Composite Well-Sections across localities in sheet 85 (Udubo), ironstone area.



Plate 8: Exposure of 'Upper' Ironstone at Dalari Quarry Pit.



Plate 9: Anticline at Bugwei, with Ironstone overlying Sandstone

and clay at Bugwei. It is also folded at Bugwei where it forms seven (7) prominent flat topped hills with lateritic capping. (Plate 9).

The deposit is being quarried extensively for road construction at Yanda and Bugwei.

CHAPTER FOUR

4.0 PETROGRAPHY/MINERALOGY

4.1 Petrography

Hand Specimen of Samples.

The clay samples are white in colour with few purple or brown stains. Samples from Tumfure and Rukwu are very smooth with very little quartz grains. Samples from Tashar Garba are gritty and yellow in colour (Table 3).

Ironstone samples are hard and rough. They contain rounded bodies in the oolitic and pisolitic facies.

4.2 Microscopic Examination of Ironstone.

Polished sections of ironstone were prepared for microscopic studies and with the aid of ore microscope, the composite minerals were identified. The main minerals recognized in the ironstone are haematite and goethite. The accessories are quartz, magnetite, muscovite, feldspar and montmorillonite. Haematite occurs as coffee - brown coloured concretions, randomly distributed within an orange to light brown groundmass in the massive facies while goethite is characterized by concentric rings round the nuclei (Plate 10). Under ordinary petrological microscope, geothite is lighter (red) in colour than haematite. Confirmation under ore/research microscope using opaque microscopy method indicates haematite as grey-white grains with bluish tint. Pleochroism and bireflectance are weak. Grey-yellowish colour was observed in anisotropy (See Appendix I.)

Quartz grains occur in all the samples but is preponderant in samples from Bugwei and Kukuruku areas in the southeastern part of the sheet. They range from angular to subangular in shape, and show moderate to weak undulatory extinction. Even the cracks which cut across the haematite grains are filled with detrital quartz (Plate 10).

4.2.1 *Texture*

There are size variations between the oolites and the pisolites. Oolites range from 0.5 x 0.5 sq cm to 1.0 x 1.0 sq. cm while the pisolites range from 0.5 x 0.6 sq. cm to 1.5 x 1.5 sq cm in size. Oolites are characterized by well - developed concentric rings round the nuclei. The nuclei are composed of geothite or detrital quartz grains. The nuclei may be rounded or ellipsoidal in shape. Each oolitic or pisolitic granule is separated with the interstices filled by quartz grains. There is no preferred orientation exhibited by the oolitic granules. The oolitic and pisolitic facies have internal laminations, in form of concentric rings. Oolites from Walwal and Bugwei especially, show perfect rings varying in number of rings from grain to grain, even on the same slide (Plate 10).

Rocks from River Mahucin Dorowa, contain some dark rounded granules suspected to be goethite.

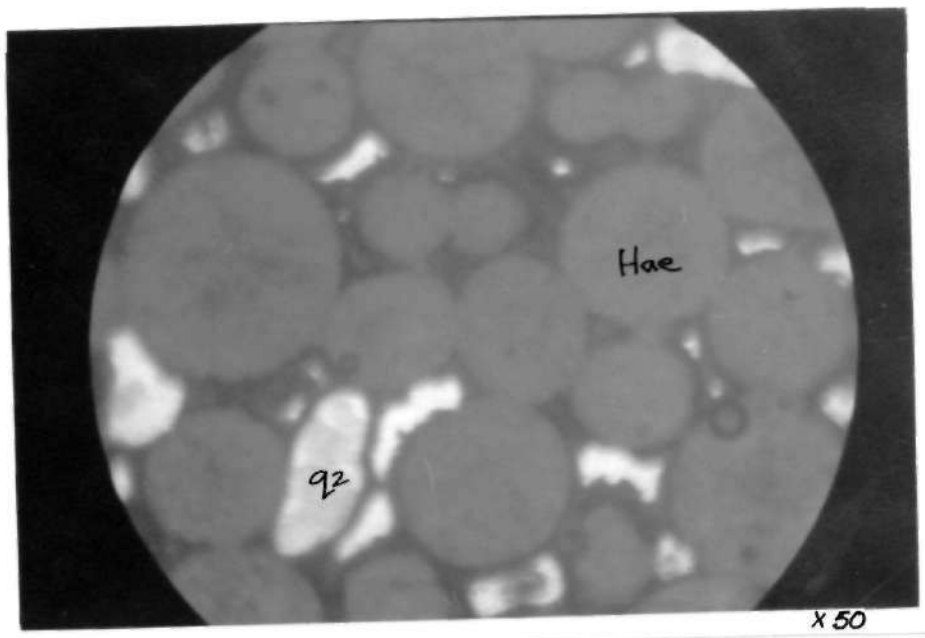
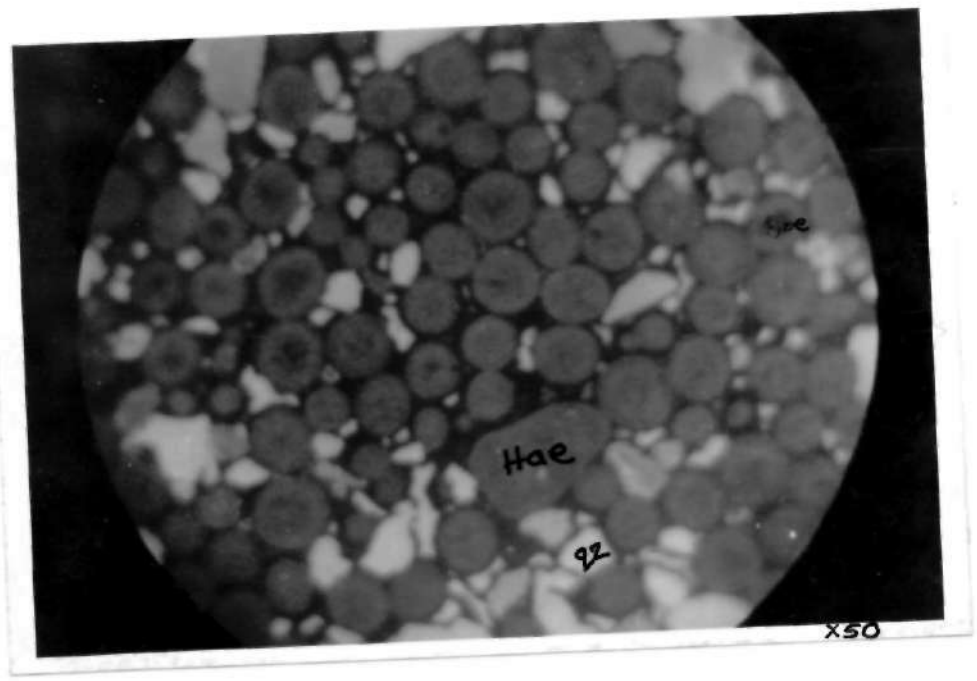


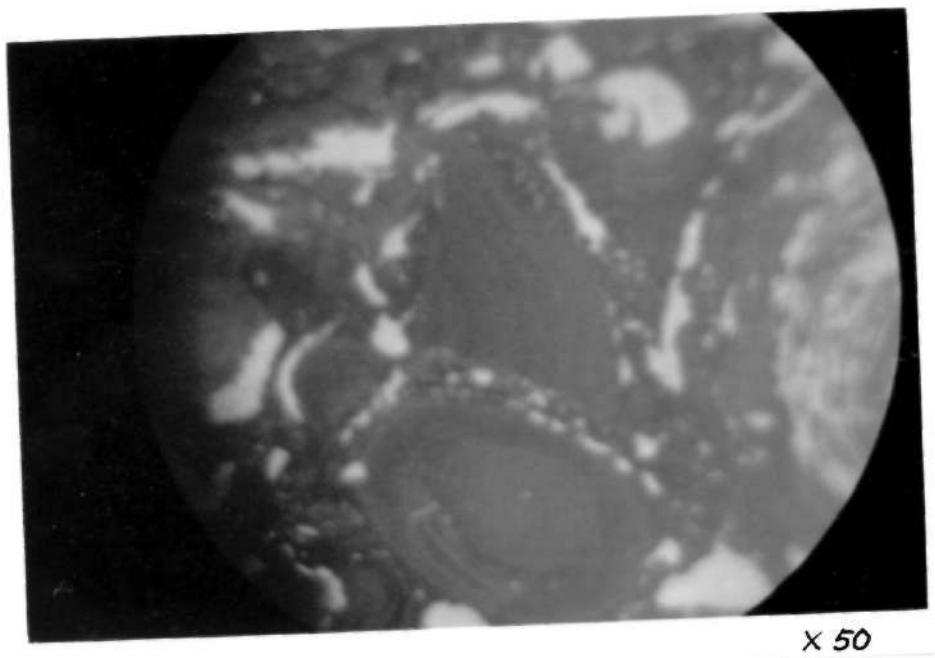
Plate 10: PHOTOMICROGRAPHS OF THIN SECTIONS OF IRONSTONE

A Oolitic ironstone displaying rounded concretions of haematite and angular quartz grains at Taranji under Plane Polarised Light (PPL). Magnification x 50.

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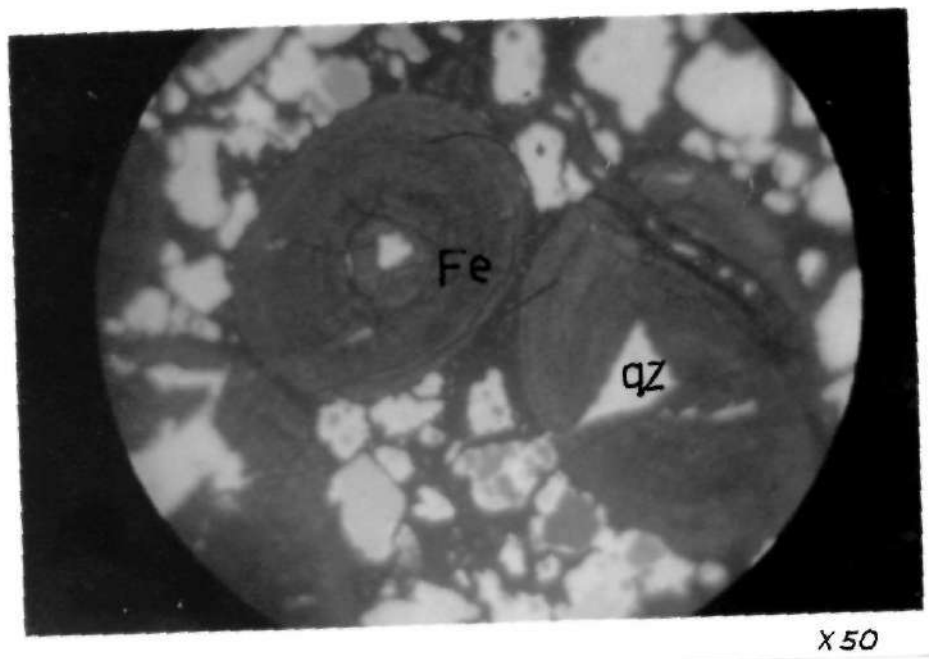


B. **Oolitic ironstone at Girin gwandi under PPL.** Mag. x 50.



C. **Pisolitic ironstone at Walwal under PPL. Mag. x 50**

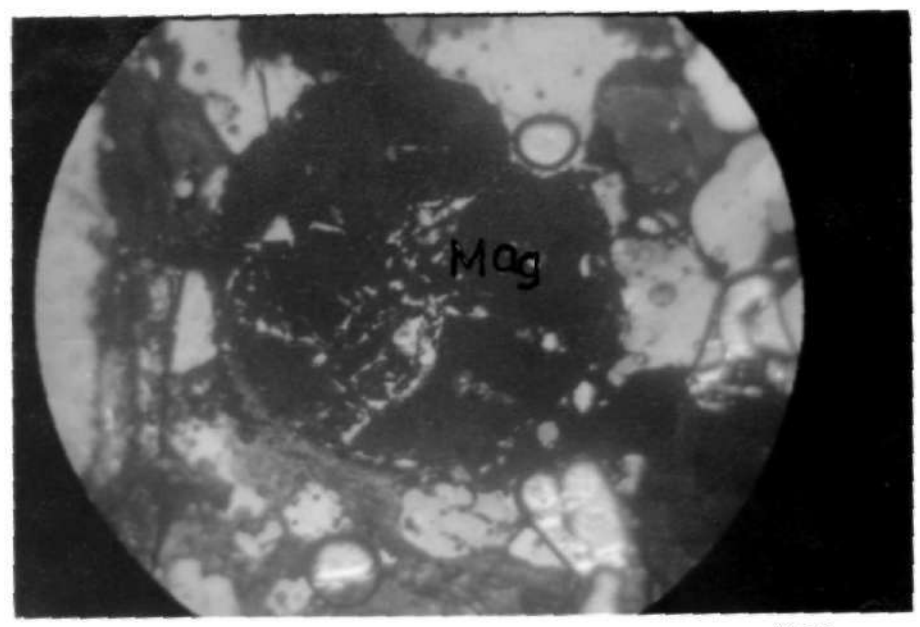
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D. **Pisolitic ironstone at Yanda under PPL. Mag. x 50.**

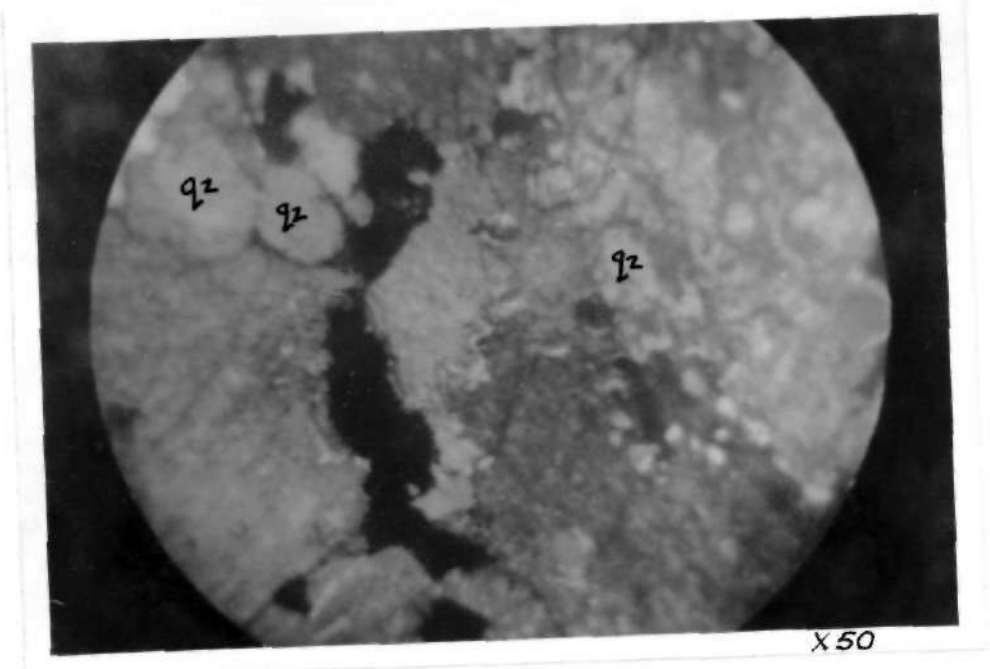


E. **Pisolites at Bugwei under PPL.** Mag. x 50.
(Pisolites badly formed at boundary of Kerri Kerri formation and Palaeozoic Basement Complex)



X 50

F. **Haematite oxidized ferric oxide (Magnetite)at Bugwei (PPL. Mag. x 50)**



G. Medium Grained Granite at Bugwei (PPL. Mag. x 50).

CHAPTER FIVE

SAMPLE PREPARATION AND ANALYSIS

5.0 Method of Analysis

The methods of analyses employed are wet chemical method, Atomic Absorption Spectrophotometry X-ray diffractometry, and Geotechnical analysis.

5.1 X-Ray Diffraction Analysis

Six (6) clay samples were analysed using the x-ray diffraction spectrometre at Steel Council Kaduna to identify the mineralogical composition of the clay. The different structural groups which characterize clay minerals were determined. Furthermore, careful x-ray work can distinguish between the structure of minerals of different chemical composition.

The differences in the stacking arrangement of the unit layers in the clay minerals which are part of the structural properties of the mineral can be detected. Crystalline impurities like quartz, calcite and other non-clay minerals can be identified. This is necessary because industries require certain specifications of kaolin.

The minerals in the powder, comprise well-ordered arrays of atoms whose arrangements characterize the spacing of planes which characterize the minerals.

Clay minerals are specifically prepared to enhance diffraction lines from planes parallel to their platy shape. For clay, a small amount of sample is used to make a slurry with water. A smear is made on a glass slide to make a thin layer of slurry. As the slide dries, flat particles orient parallel to the plate. The peaks of diffraction is in (Fig. 10). The result of XRD is shown graphically in Fig. 9 and diffraction values on page 61.

5.2 Wet Chemical Analysis.

For the wet chemical analysis, the sample preparation required that one gram of each sample to be weighed into a teflon crucible and moistened with distilled (deionized) water. Hydrofluoric (HF) acid is added to top the crucible and then placed on a sand bath at 300^{O}C to evaporate to dryness. The final residue is then dissolved in 1:1 HCl and distilled water, 10 ml of saturated boric acid is also added to stabilize the ions in solution. Each solution is then made up to 100 ml by the diluted HCl acid. It is then shaken vigorously using an Sm 100^{R} machine of Geological Survey Department Laboratory, Kaduna, until a homogenous solution is obtained for each sample. Then it is removed and set aside for the wet chemical analysis. The chemical composition of the ironstone and the clay are shown in tables 5 & 6, and the procedure is outlined in Appendix II.

5.3 Atomic Absorption Spectrophotometry (AAS).

The AAS machine Perkin Elmer R model 290B of Institute of Agricultural Research, Ahmadu Bello University, Zaria, was used for the determination of Magnesium (Mg), Iron (Fe), Manganese (Mn) Silicon (Si) Aluminium (Al) and Titanium (Ti) elements which were later converted into their oxides.

A small amount of each sample solution was vapourised by an air acetcylene flame at a temperature of about 2000^{O}C sufficiently high to reduce most of the ions in solution into atomic form. The vapour was illuminated by a light source from a discharge lamp of the same element as that being determined. Characteristic atoms of this element in vapour

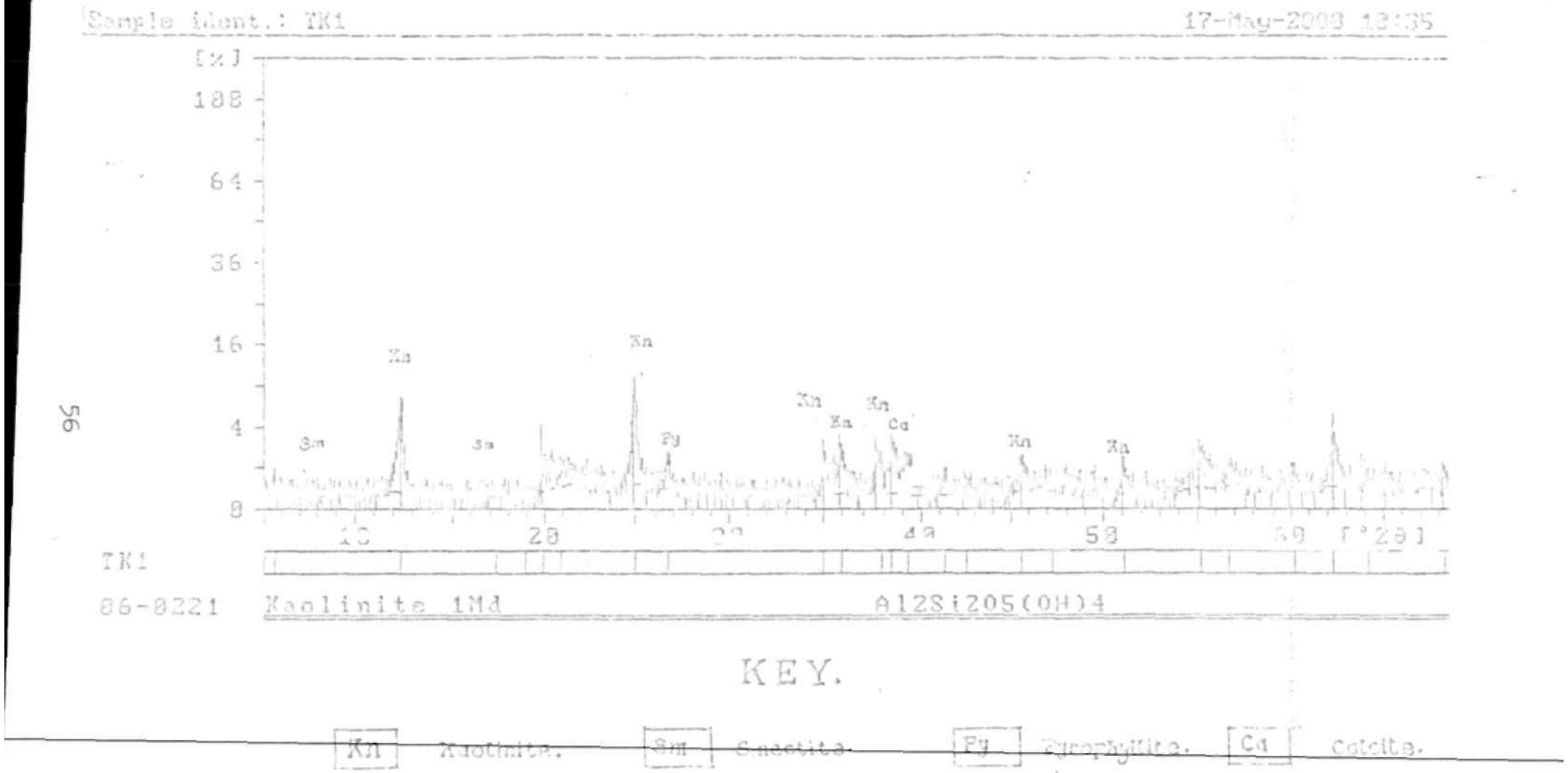


Fig. 9a. X-ray analysis result for Tumfure clay

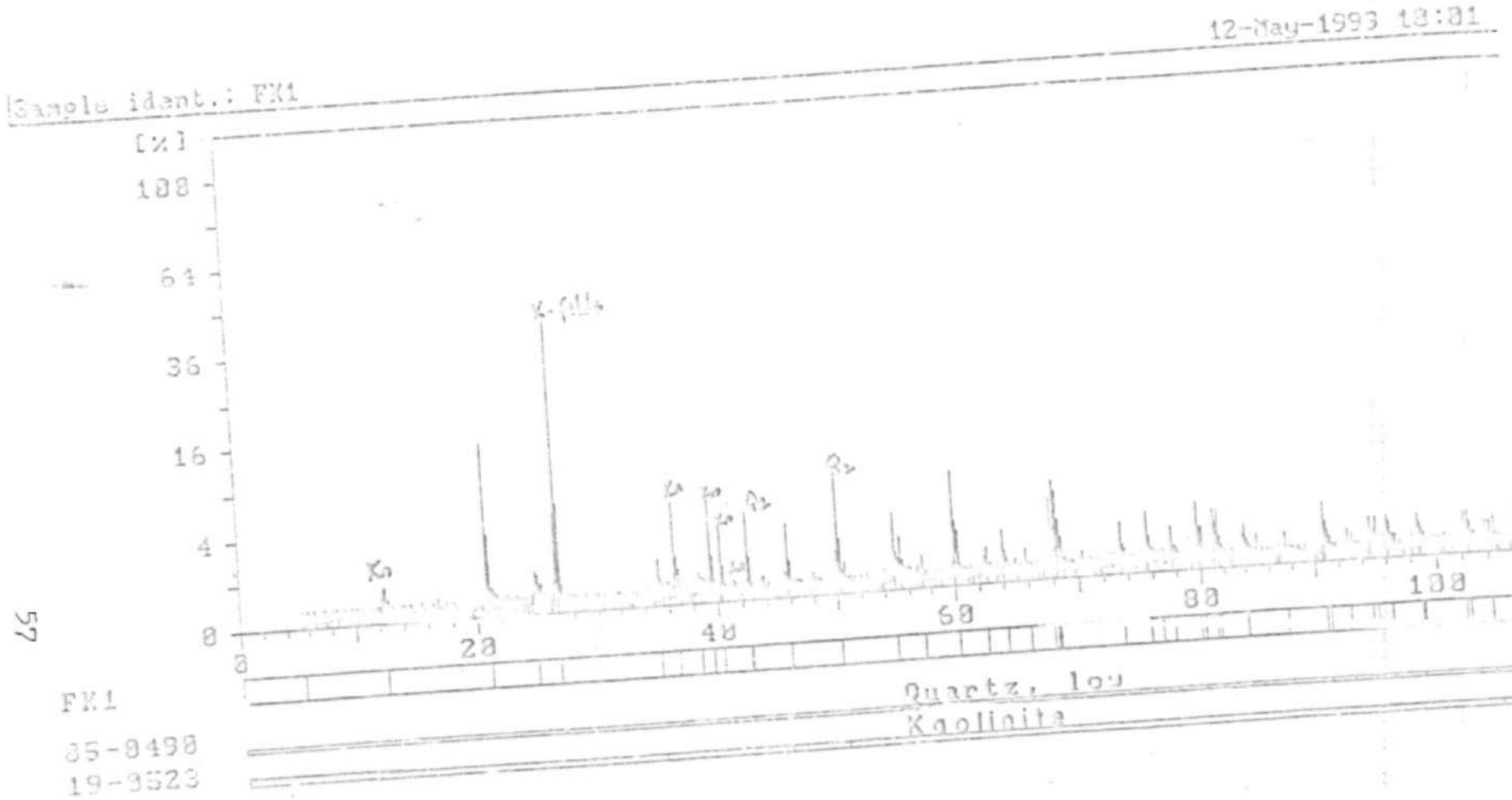


Fig. 9b Result of XRD for Fkli clay.

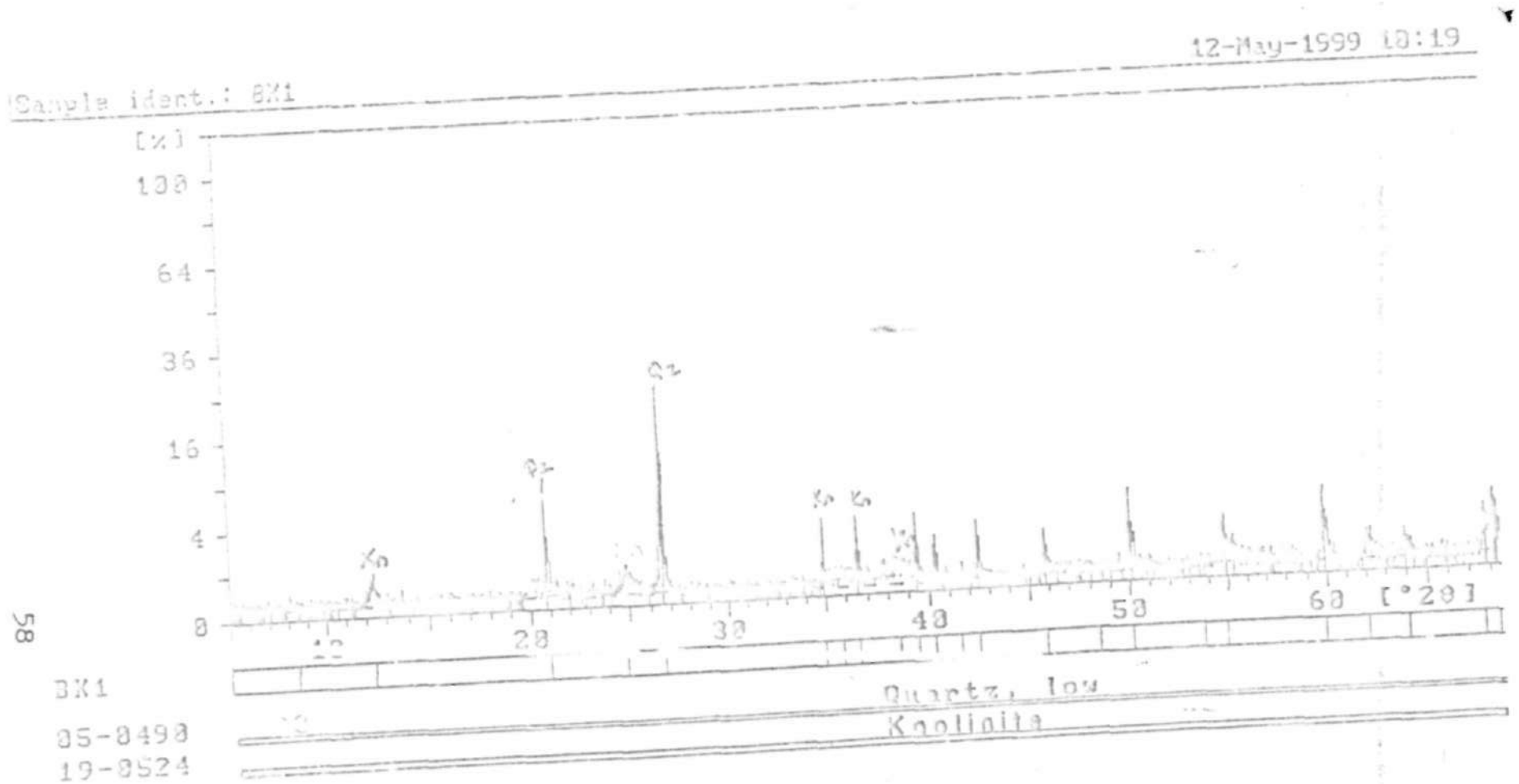


Fig 9c. Result of XRD for Bugwei clay

absorbs radiation from the lamp. The amount of absorption is proportional to the concentration of the element in vapour. The appropriate lamps for absorption of each element were used. This gives a value on the analog scale which when converted using the formula below gives the concentration of the element (Table 5). The formula for calculating the concentration of the elements in parts per million (ppm) is shown below:-

$$E\ (ppm) = \frac{ug/ml \times Dilution\ factor}{weight\ of\ sample}$$

ug/ml = Extrapolated element content recorded based on those of the standards

3b. Diffraction Values for Minerals in Clay Samples

Value of diffraction peaks of minerals in clay samples are shown below:

A. Tumfure Clay

i. Kaolinite $Al_2Si_205(0H)_4$

∠2θ	d - value - Å
12.38	7.15
24.95	3.56
35.97	2.49
37.90	2.37
47.21	1.92

ii. Smectite $(Al_2Si_4010(0H)_2$

2θ	d - value Å
5.20	3.40
10.46	15.99
15.60	8.45
31.84	5.68

iii. Pyrophyllite $(Al_2Si_4010(0H)_2$

∠2θ	d - value
9.65	4.58
20.08	9.16
26.60	4.42
29.28	3.35

B Fili Clay

i. Kao linite

∠2θ	d - value
12.38	7.14
24.95	3.57
36.06	3.57
38.46	2.49
38.50	2.34

ii Quartz $Si0_2$

2θ	d - value
42.63	2.12
45.88	1.97

C. Bugwei Clay

i. Kaolinite

2θ	d - value
12.32	7.18
24.79	3.50
35.78	2.51
38.54	2.33

ii. Quartz $(Si0_2)$

∠2θ	d - value °A
20.85	4.26
26.67	3.34
36.55	2.46
39.41	2.28

Iii Calcite $(CaCo_3)$

∠2θ	d - value °A
23.04	3.04
39.34	3.86
39.52	2.29
43.07	2.28

Iv. Goqthite Feo (0H)

∠2θ	d - value °A
36.06	2.69
36.67	2.49
41.22	2.45

Table 4. GEOCHEMICAL ANALYSES OF MAJOR AND TRACE ELEMENT IN IRONSTONE SAMPLES IN UDUBO AREA. RESULT OF ATOMIC ABSORPTION SPECTROMETRY (AAS)

Localities	Bulaudo	Zindwa	Taranji	Taranji	M.Dorowa	Waiwai	Waiwai	Kurukuru	Kurukuru	Bugwei	Bugwei
Sample Number / Elements	Fe051	Fe052	Fe053	Fe054	Fe055	Fe056	Fe057	Fe058	Fe059	Fe060	Fe061
Fe	32.5	30.38	37.5	33..75	37.5	13.13	17.5	26.88	31.89	31.88	18.75
Cu	0.01	0.01	0.02	0.02	0.14	0.01	0.01	0.01	0.01	0.01	0.01
Ca	0.04	0.11	0.06	0.08	0.04	0.02	0.04	0.04	0.04	0.02	0.02
Mg	0.02	0.04	0.02	0.02	0.03	0.00	0.01	0.02	0.01	0.01	0.01
K	0.02	0.02	0.02	0.03	0.00	0.01	0.04	0.04	0.04	0.03	0.02
Mn	0.08	0.11	0.30	0.17	0.20	0.12	0.03	0.07	0.14	0.16	0.02
Na	0.09	0.60	0.11	0.06	0.06	0.01	0.13	0.03	0.06	0.05	0.20
Cr	0.34	0.31	0.33	0.34	0.36	0.18	0.21	0.26	0.31	0.30	0.20
Ni	0.14	0.13	0.14	0.15	0.13	0.06	0.10	0.08	0.13	0.13	0.08
P	0.50	0.43	0.67	0.30	0.50	0.17	0.11	0.23	0.21	0.27	0.11
S	0.0	0.0	0.0	0.01	0.3	0.1	0.3	0.2	0.0	0.3	0.3

Statistical data for ironstone samples.

M- 28.33
V- 68.66
SD- 8.28

M- 0.264
V- 0.002
SD- 0.046

M- 0.024
V- 0.0002
SD- 0.013

M- 0.024
V- 0.0004
SD- 0.020

M- 0.022
V- 0.0002
SD- 0.013

M- 0.23
V- 0.007
SD- 0.081

M- 0.08
V- 0.03
SD- 0.17

M- 0.29
V- 0.004
SD- 0.063

M- 0.12
V- 0.001
SD- 0.03

M- 0.33
V- 0.03
SD- 0.18

M- 0.14
V- 0.02
SD- 0.14

Key

M-Mean
V-Variance
SD-Standard Deviation-

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TABLE 5 RESULTS OF ANALYSES
(WET CHEMICAL ANALYSIS OF TARANJI AREA IRONSTONE SAMPLES)

Major Elements	FC 051	FC 052	FC 053	FC 054	FC 055	FC 056	FC 057	FC 058	FC 059	FC 059	FC 060	
Locality	Bulaudo	Zindiwa	Taranji		M.Dorowa	Walwal	Walwal	Kurukuru		Bugwei	Bugwei	
SiO_2	11.84	11.85	8.29	18.08	18.09	18.02	18.04	20.60	27.98	21.66	21.63	T-258.45 V-65.69 M-23.50 SD- 8.105
TiO_2	0.01	0.01	0.02	0.03	0.03	0.05	0.05	0.01	0.00	0.03	0.03	T-0.19 V-0.0245 M-0.0173 SD-0.157
Al_2O_3	4.71	4.72	5.45	6.40	6.49	4.86	4.87	3.84	2.81	8.16	8.15	T-60.46 V-2.801 M-8.496 SD-1.674
Fe_2O_3	70.28	70.27	71.87	63.87	63.88	67.87	67.87	63.88	59.89	59.89	59.85	T-719.42 V-17.63 M-65.40 SD-4.198
MnO	0.00	0.00	0.01	0.51	0.50	0.05	0.05	Trace	Trace	0.05	0.05	T-1.22 V-0.044 M-0.136 SD-0.21
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	T-NIL V-NIL M-NIL SD-NIL
CaO	0.00	0.00	0.00	0.00	Trace	Trace	Trace	0.00	0.00	Trace	Trace	T-NIL V-NIL M-NIL SD-NIL
P_2O_2	N.D.	N.D	N.D	0.03	0.00	0.0	0.00	N.D	N.S	0.00	0.00	T-NIL V-NIL M-NIL SD-NIL
H_2O	12.03	13.20	13.20	10.37	10.37	9.07	9.07	11.34	9.17	10.24	10.23	T-118.25 V-2.295 M-10.75 SD-1.52
H_3O	0.98	1.15	1.15	1.12	1.12	0.94	0.94	0.8	0.36	0.37	0.37	T-9.30 V-0.11 M-0.845 SD-0.33
Total	99.85	101.2	99.99	100.41	100.48	100.86	100.89	100.05	100.21	100.4	100.31	

N.D. Not Determined

Key
T = Total
M = Mean
V = Variance
SD = Standard Deviation

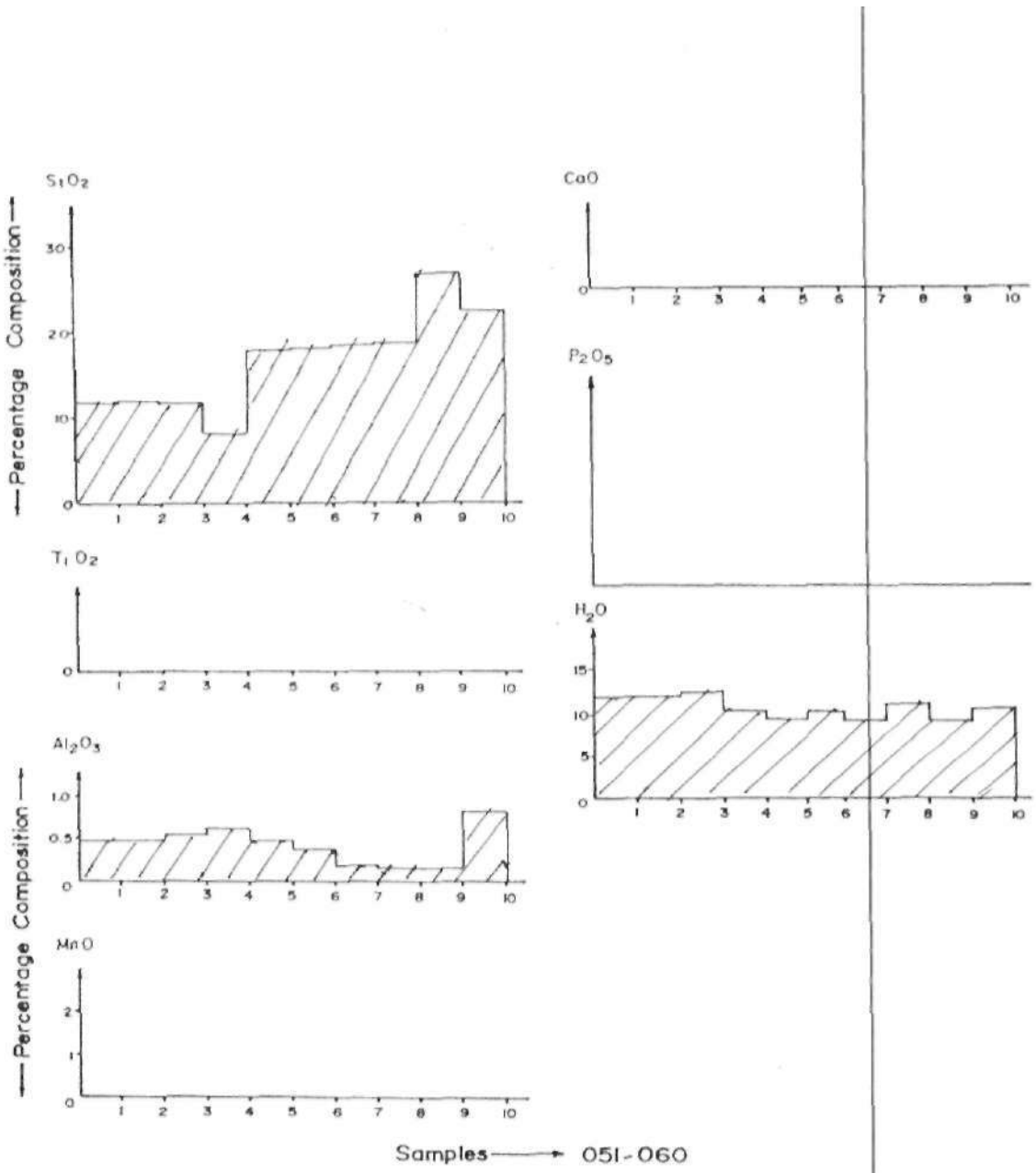
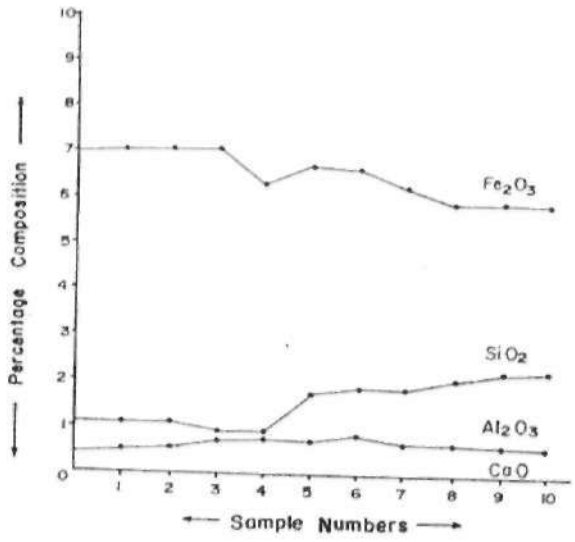


Fig-19. Histograms showing the composition of oxides in Ironstones samples.



Fig·10b-Distribution of Fe_2O_3, SiO_2 and Al_2O_3 in samples. in fronstone samples.

KEY

T = Total
M = Mean
V = Variance
SD = Standard Deviation

TABLE 6: RESULT OF CHEMICAL ANALYSIS OF KAOLIN SAMPLES COMPARED WITH SOME REFERENCE SAMPLES

	Loc: Tumfure			Rukwu			Tashar Garba			Reference Samples (i) (ii)		
MAJOR OXIDES	FC 064 (a)	(b)	(c)	FC 065 (a	(b)	(c)	FC 066 (a)	(b)	Average	Crimsha Standard	Ikot-w Igwe	
$S_1?_2$	44.88	44.89	44.87	43.73	43.73	43.72	54.34	54.34	47.7	40-60%	46.66	T-42.20 V-19.22 M - 46.91 SD-4.38
TiO_2	0.04	0.04	0.04	0.18	0.17	0.04	0.80	0.81	0.34			T-2.46 V-0.101 M-0 27 SD-0.318
FeO_3	2.23	2.24	2.24	1.60	1,60	1.60	1.60	1.70	1.62	25-45%	34.04	T-10.48 V-0.181 M-2.054 SD0.425
AlO_3	39.00	39.01	39.00	46.24	46.24	46.23	32.82	32.8	36.0	1-5%	4.26	T-318.34V - 29.79 M-39.29 SD-5.46
MnO	2.23	2.24	2.24	1.60	1.60	1.40	1.60	1.82				T-16.88 V-0.111 M-1.81 56-0.833
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	00	0.25	0.25	T - V - NILL M - NIL SD NILL
$_2Ca$	0.00	0.00	0.00	0.26	0.25	0.25	0.13	0.13	0.13			T - 1.15 V-0.0121 M-0.128 SD-0.11
P_2O_5	N.D	N.D	N.D.	0.00	0.00	0.00	0.00	0.00	0.00			T- V-0.0121 M - NIL SD - NIL
H_2O	13.28	13.29	13.27	8.20	8.23	8.22	9.66	9.65	7.35			T-01.15 V-6.112 M-10.13 SD-2.47
H_3O	0.4	0.4	0.4	0.42	0.42	0.42	0.28	0.28	3.71			T-6.78 V-1.238 -0.75 SD-1.113
Total	102.06	99.82	102.06	100.81	102.2	101.8	99.80	101.31	98.67			
Loss on ignition		102.11	101.23	102.23						5-14	13.05	
Impurities										3	1.43	

Table 7. THERMOGRAVIMETRIC ANALYSIS OF CLAY

	Location	Description of Sample
SAMPLE NO. 064	Tumfure	Buff white to beige, fine massive clayey rock. Moderately indurated
065	Rukwu	Clayey rock with white to buff fine-grained silica sand
066	Tashar Garba	Buff-white yellowish clayey rock.

LOCATION	SAMPLE NO.	% WEIGHT LOSS AT 110°C	% WEIGHT LOSS AT 1000°C	APPROXIMATE KAOLINITE %
Tumfure	FC 064	0.14	13.29	94.75
Fili	FC 065	0.42	8.20	58.17
Tashar Garba	FC 066	0.28	9.66	68.51

Table 8(a)

Sample No. .Liquid Limit = 29%..... .....Plastic Limit .....14.94%.....

Date....26/8/97..... Plasticity Index.... 14.06.....Linear Shrinkage....5.71%...

Job.....Description of soil.....

Site.....

L. L. Machine No.....Operator..... .....

Proportion of sample retained on No.....6 BS Sieve.....

No. Of blows refers to liquid limit determination.

Shrinkage % refers to Linear shrinkage.

Liquid limit marked L.L. Plastic limit marked P.L. Shrinkage limit marked

Type of test	LL		LL		LL		LL		LL	
No. of blows/shrinkage %	42		36		25		11		14	
Container No.	149		143		150		152		179	
wt of wet soil and container	29.60		31.15		35.15		31.20		29.90	
wt. of drained soil and cntainer	25.35		26.30		28.80		25.75		24.55	
wt. of container	8.30		8.45		8.30		8.30		8.35	
wt of dry soil (wd)	17.05		17.85		17.45		17.45		16.70	
wt. of moisture (wm)	4.25		4.85		5.45		5.45		5.35	
Moisture content (wm/wd)	24.93		27.13		31.23		31.23		33.03	
Type of test		PL		PL		PL		PL		
No. of blows/shrinkage %		-		-		-		-		
Container No.		175		173		178				
wt of wet soil and container		11.90		15.20		15.14				
wt. of drained soil and container		11.40		14.30		14.25				
wt. of container		8.10		8.30		8.45				
wt of dry soil (wd)		3.30		6.0		5.80				
wt. of moisture (wm)		0.50		0.90		0.85				
Moisture content (wm/wd)		15.15		15.00		14.66				

Original length 14cm
Final length 13.20
Shrinkage 0.80
Shrinkage % 5.71%

Table 8(b)

BUG WAE
CLAY

Sample No. .Liquid Limit = 29.55..... .....Plastic Limit .....11.13%.....
Date....26/8/97..... Plasticity Index.... 18.37%.....Linear Shrinkage.....6.79%...
Job.....Description of soil.....
Site.....
L. L. Machine No.....Operator..... .....
Proportion of sample retained on No.....6 BS Sieve.....
No. Of blows refers to liquid limit determination.
Shrinkage % refers to Linear shrinkage.

Liquid limit marked L.L. Plastic limit marked P.L. Shrinkage limit marked

Type of test	LL		LL		LL		LL		LL	
No. of blows/shrinkage %	43		34		25		18		11	
Container No.	66		77		24		111		11.9	
wt. of wet soil and container	60.50		49.90		38.40		36.80		29.05	
wt. of drained soil and cntainer	58.00		43.60		34.30		33.0		23.50	
wt. of container	20.50		20.70		20.60		21.0		8.30	
wt. of dry soil (wd)	38.00		22.90		13.70		12.0		15.20	
wt. of moisture (wm)	8.50		6.30		4.1		3.8		5.55	
Moisture content (wm/wd)	22.40		27.5		29.9		31.7		36.51	
Type of test		PL		PL		PL		PL		
No. of blows/shrinkage %		-		-		-		-		
Container No.		80		32		12				
wt. of wet soil and container		26.00		36.10		26.80				
wt. of drained soil and container		25.50		25.50		26.20				
wt. of container		20.20		20.80		21.00				
wt. of dry soil (wd)		5.5		4.7		5.2				
wt. of moisture (wm)		0.5		0.6		0.6				
Moisture content (wm/wd)		9.1		12.8		11.5				

original length = 14.00cm
dry length = 13.05cm
shrinkage = 0.95
Shrinkage % 6.79

5.4.1. Geotechnical Properties of Clay (Atterberg Limits)

Liquid Limit.

The liquid limit is the water content at which measurable shear strength is first apparent and it marks the boundary between the liquid and plastic states.

The liquid limit of samples has a range of 29.0 - 29.5%

Plastic Limit

The plastic limit is the water content at which a paste is formed and thread 1/8" diameter rolled around clay without crumbling. This marks the boundary between the plastic and the semi-solid states. (Karol, 1960).

The plastic limit ranges from 11.13 - 14.94% thus have an average of 12.53 in the samples analysed.

Plasticity Index

The range of water content throughout which a soil exhibits plastic properties is called the plasticity index.

Plasticity index ranges from 14.06 - 18.37, therefore it has an averages plasticity index of 14.94% in the clay.

Linear Shrinkage.

The smallest water content at which a soil can be completely saturated is called the shinkage limit. This value marks the boundary between the semi-solid and solid state. (Karol, 1960).

The linear shrinkage of the clay ranges from 5.71 - 6.79%, therefore average liquid shrinkage of 5.75%

5.5.1 Interpretation of Wet Chemical Analysis Result on Kaolin Samples

The wet chemical analysis indicate Silica (SiO_2) and Alumina (Al_2O_3) as the main oxides of the clay. Fe_2O_3, TiO_2, CaO, MnO are the minor oxides (Table 5). Silica is the most abundant oxide. It has the highest composition with an average of 47.7% in the samples. Samples from Tashar Garba contain the greatest amount of silica. Alumina is the second main oxide. It has an average composition of 36.0%. Iron oxide is the most important minor oxide with an average composition of 1.82% in the samples. Titanium oxide occurs as a minor oxide, with an average composition of 1.82%. The third minor oxide is manganese oxide which has average composition of 1.82%. MnO and CaO occur in traces with averages of 0.8 and 0.13% composition respectively. H_2O/H_3O has total composition of 7.4%.

1. a. The clay was determined thermogravimetrically as kaolin and XRD as kaolinite (Table 7). Other minerals in the clay include Dickite. Dickite is a polymorph of kaolin.

   b. Geotechnical analysis result of a liquid limit of 29.25%, plastic limit of 12.53 and plasticity index of 14.94% indicate tough tensile strength of the clay. Linear shrinkage of 5.75 indicate ability to withstand stress and heat resistance (Table 8).

2. The wet chemical analysis result indicate that SIO_2, Al_2O_3, Fe_2O_3, MnO, CaO are present (Table 6 AAS) which suggest a granitic origin or source rock for the clay.

3. The SiO_2:Al_2O_3 ratio is low, 47.7% to 36.6%, explaining the negligible amount of free quartz grains found in the samples, thus the clay is smooth. Alkali metal oxides (CaO/ C_2O and Na_2O) content is low too. Phosphorous is not detected

which is good for the refractory industry, as phosphorous produces pungent fumes unwanted in industries.

4. At Tumfure - iron content is low but titanium oxide (TiO_2) is present, therefore, iron may occur in form of complexes such as ilmenites ($FeTi0_3$) which is exhibited as purple stains or tint on the samples. The average Fe_2O_3 is high in samples from Tashar Garba. The range is 1.60 - 1.70 i.e an average of 1.65, therefore, samples are milky in colour but within tolerable limits for refractory production.

5. The amount of oxides is dependent on the source material, although direct relationship between chemical composition and origin is hard to establish, but rocks with greater than 40% SiO_2 are granitic in origin.

6. The chemical composition of the clay is close to ideal composition of 46.54% SiO_2, 39.5% Al_2O and 13.9% H_2O known as the process of kaolinization. Therefore, the clay contains negligible free quartz, therefore, non - gritty.

7. Due to removal of Si, kaolinite possesses greater SiO_2:Al_2O_3 ratio than other clay minerals because potassium and sodium tend to flocculate Si and keep it in the weathering solution. This is responsible for rapid kaolinization of acid granitic rock, rich in K and Na over rocks with Ca and Mg. The weathered product may remain in situ or it can be transported and deposited elsewhere.

8. In application, like the ceramics where high plasticity is desired, high alkali metal content is required, but for refractory production, chemical purity and homogeneity are the major demands on the clay. Thus, alkali metal content which is low in this kaolin renders the clay potentially suitable for refractory production. But industries blend raw materials by adding raw materials as desired.

5.5.2 INTERPRETATION OF RESULT OF LABORATORY ANALYSIS OF IRONSTONE

Samples are labelled FC 051 - 061

The oxide analysis or wet chemical analysis results indicate Fe_2O_3 and SiO_2 as the major oxides while Al_2O_3, TiO_2 and MnO occur as traces. The Fe_2O_3 occur in varying amounts from 59% - 72%. Average total iron (Fe) is 33% from the result of atomic absorption spectrophotometry. TiO_2 and Manganese have average of 0.02 and 0.08 ie occurring as traces in the samples analyzed, (Table 5 and Fig. 9). Sample FC 055 from Taranji and Walwal areas have the highest content of iron, (Table 9), therefore the ironstone is purer in Taranji area.

Phosphorous and sulphur - the two main deleterious constituents undesired in iron and steel industry occur in tolerable limits of less than 0.4 (0.4 is the upper limit required in the steel industry). Iron occurs mostly as haematite, but because of the high loss on ignition values, samples are suspected to contain limonite and turgite (Tables 2 & 5).

Haematite is a common iron of sediments and metamorphosed sediments, while limonite is a weathering product of iron containing minerals.

Quartz grains occur in all the samples, but is abundant in samples from Bugwei and Kukuruku areas in the southern part of the sheet. The quartz ranges from angular to subangular in shape and show moderate to weak undulatory extinction, under cross nicols. Even the cracks, which cut across the haematite grains are filled with detrital quartz in samples from Bugwei.

Generally, the iron deposit fines upward the sheet. This view is corroborated by the higher iron content from Taranji, Walwal areas in the northern half, in comparison with samples from Bugwei and Kukuruku areas in the southern part, with much angular quartz grains.

CHAPTER SIX

6.0 DISCUSSION

Kaolin is a white clay consisting of kaolinite $Al_4Si_4(OH)_{10}$ also nacrite, dickite and anauxite etc. These three minerals are polymorphs. Halloysite, endellite and allophane may be included although they are structurally different and secondary. Hydrolysis of primary silicates in clay minerals leads to the removal of alkali and alkaline earth metals which when replaced by hydrogen ion (H^+) gives kaolin. The removal of Si is facilitated by the presence of K and Na which tends to keep Si in solution. Ca and Mg tend to flocculate Si and ensure its retention in the weathering environment. The weathered product may or may not be transported from the source rocks.

Mapping and interpretations were made on actual outcrops or exposures. The analysis of samples were done and the composite minerals were identified and the reserve estimated.

Tests to determine colour, particle, size, distribution, brightness, viscosity, must be conducted to enhance the value as certain industries require different specifications of kaolin. The presence of impurities affect the end product of manufacture. Quartz and other abrasives affect the surface gloss, thereby, reducing smoothness required in high quality paper, if kaolin is used as coating pigments. The clay at Tumfure contains less than 4% quartz, smooth to touch.

Organic materials produce large pigments which exhibit a dull appearance on wares while soluble salts and exchange ions can affect the property, in industries that need no flocculation, before utilizing the kaolin, Tumfure clay is bright and white.

Kaolin is processed by crushing, using mills and beneficiation by separation

processes such as flocculation, sedimentation and drying to enhance brightness and smoothness. Greene and Duke (1962), suggested selective flocculation and magnetic separation methods of beneficiation for removal of iron and titanium to enhance brightness to range of 90%.

Calcium may be added to kaolin to manufacture special products, which have higher resistance to abrasion. In paints industry, purer kaolin consisting of greater than 85% kaolinite is required, but wide range in particle size are useful. Coarse particle kaolin are used for paints with dull or flat finish while fine particle size produce high gloss paints. The Kaolin at Tumfure contains 94% Kaolinite in its raw state.

The ironstone specimen in the study area contains total iron oxide (Fe_2O_3) content ranging from 60% - 72%. This has an average of 68% Fe_2O_3. Average total iron (Fe) in the study area is 33%.

The average phosphorous content in this study area is 0.32% while Sulphur is 0.02%, thus, the, ironstone is suitable for use in iron and steel industry. Deleterious constituents raise the temperature in the furnace and their oxides and gases are difficult to separate from the melt in the furnace. The ideal standard of < 0.2% sulphur and < 0.4% phosphorous is recommended in steel industry. Recent technology converts phosphorous to lime for fertilizer manufacture (Astier et al, 1989).

Beneficiation will enhance the quality, beneficiation of ironstone involves two steps. First, the reduction of the iron ore to pig iron and secondly, the treatment of the pig iron to make cast iron, wrought iron or steel. The ore is smelted with coke and limestone. Air or oxygen is blown in at the bottom, it burns coke to Carbon Monoxide (CO), which removes oxygen from the iron ore, reducing it to the metal. The limestone slags off the silica and other impurities.

6.1 SUMMARY

The field study revealed that the thick pile of sediments in the Chad Basin is underlain at far depth by granite. The granite comprises more than 85% quartz at Bugwei where contact between the Kerri Kerri Formation and the basement complex was found. Only small feldspar occur in the granites.

Chad Formation comprises of loose sand. Geological structures are essentially beddings, faint cross - lamination, oolitic and pisolitic concretions in the ironstone. Trends show north - northeast to south - south west (NNE - SSN) directions. The loose sand masks the geology and hides the resource potential in the subsurface as the ironstone and kaolin are rarely exposed. The geochemical sampling in the area revealed that the chemical composition of ironstone is high.

6.2 CONCLUSION AND RECOMMENDATION

The trough - like feature/structure of the Chad Basin facilitated accumulation of thick and extensive pile of sediments within the basin, thus, the thickness of over fifty metres (>50m) for the clay and the ironstone are expected. The thickness though it varies, has an average of 26m for the clay and >30m for the ironstone. At Bugwei well, the clay is over three hundred metres (>300m) thick.

Results of geochemical analysis and thermogravimetrical analysis indicate 94% kaolinite and 4% quartz for Tumfure kaolin. Quartz and iron oxides occur as impurities in negligible amount, thus, the kaolin is of high quality and can be used in its raw state.

The ratio of silica:alumina 47.7:39.0 for clay at Tumfure and Rukwu is high. This suggests that the quality of free quartz is negligible especially at Tumfure. Alumina controls refractoriness, therefore the clay's refractoriness is high. The average of 2.24 iron oxide is due to the occurrence of haematitic ironstone in the area. Titanium oxide is present, therefore the iron oxide may occur also as complexes such as ilmenite ($FeTiO_3$)The lime and magnesia content is low and therefore may have a negligible effect

on the swelling index and other properties.

The loss on ignition of 14.71 and 5.71 on wet and dry samples respectively shows great potential of the clay to absorb water. A fireclay is a good refractory material when it's range of chemical composition falls within values given by Grimshaw (1975) in Table 4. The clay is a very good refractory material.

The ironstone specimen contain total iron oxide (Fe_2O_3) percentages varying from 59.89 - 72%. Average total iron is 33%, phosphorus 0.3% and sulphur 0.1% contents are within tolerable limits of 0.4 and 0.3, respectively. They are made up mostly of haematite but because of high loss on ignition values, they are suspected to contain also limonite and turgite hematite with absorbed water. Haematite is a common iron of sediment and metamorphosed sediments while limonite is the weathering product of all iron containing minerals.

Open earth mining method is recommended, blasting may be required in places with thick overburden.

Contribution of this Work

The contribution of this work is are:

1. A detailed geological map of an area saddled with dearth of geological information is now available.
2. The discovery of the ironstone and the clay deposits is useful
3. Research into the geochemical composition of the ironstone and the clay will promote mining and utilization of resources.
4. Detailed stratigraphy, now made available will boost hydrogeological prospecting.

The inhabitants suffer lack of water, provision of water by getting rid of the ironstone will provide water for drinking and agricultural purposes.

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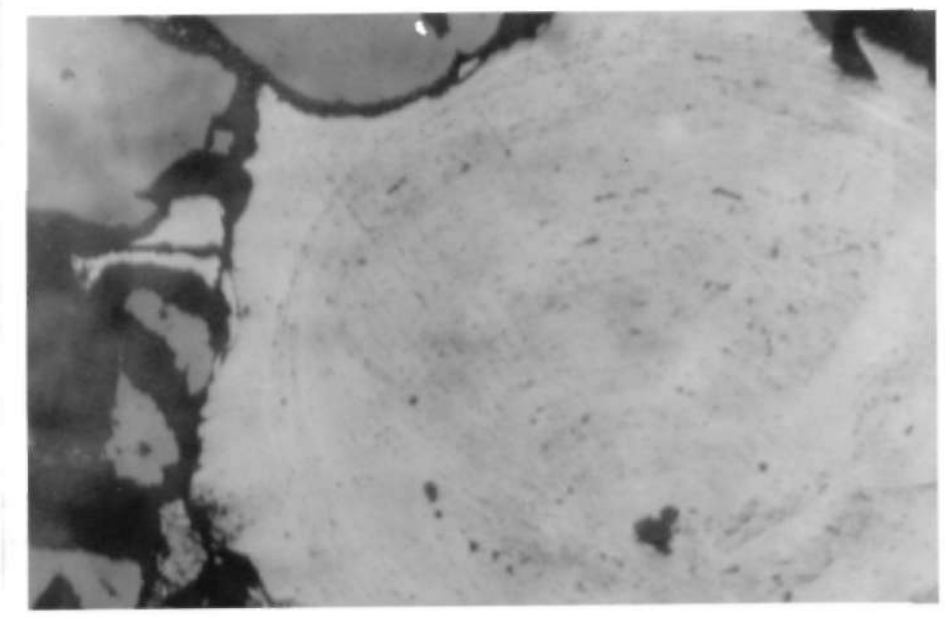
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APPENDIX I



Photomicro graph of ironstone under ore/research microscope, using opaque microscopy method. Haematite is yellow in colour. Angular quartz grains occur as impurities. Magnification x 50.

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APPENDIX II

LABORATORY PROCEDURE OF WET CHEMICAL ANALYSIS

Pulverize the sample, ass Hf and Hcl to dissolve, heat on a sand bath, use glass rod to break all the crystal lattices of elements (compounds) and heat in a fume cupboard. Allow the constant temperature for one hour in the furnace cupboard. Bring the crucible and the heated mixture in an evaporating dish. As it cools, it cakes, then fill the content with 1:1 hydochloric acid to ensure complete digestion.

The solution is put under ultraviolent lamp and evaporated to dryness. Test for dryness by bringing ammonium hydoxide close to the dish. If it fumes, it means that ammonia is still reacting with chlorine to form ammonium chloride. If there is no fume, it means the reaction of Ammonia is complete and heated mixture is completely dry.

Wet the side of container with droplets of 1:1 HCl, add H_2O and ensure complete solution or dissolving. Boil for 3 minutes on hot plate to enable complete dissolving. Then filter with watts man filter paper 541. The filtrate goes into a beaker.

The residue in the funnel and silica (Si) is trapped. The Si is dried in the oven. Put Si in the crucible, burn at 1000c at constant temperature for about thirty (30) minutes, remove, and put in desicator for cooling, after cooling weigh - the difference in silica.

$$\frac{\text{Wt of residue} \times 100 = \text{true silica}}{1g} \qquad = \text{true silica}$$

Weight 0.5 or 1g pulverized sample.

For dofium and potassium, solution was run in a A.A.D. or flame photometer with sodium or potassium filter (as appropriate).

Value on the screen multiplied by factor from graph - standard graph will give the concentration. This is the percentage sodium (Na) or Potassium (K) in the sample (P_2O2_5 Al_2O_3, MnO, TiO_2 members R_2O_3 group major elements are what we have got).

The acid filtrate in the beaker is turned into base. Add 5ml H_2O_2, boil on a hot plate and after boiling, use ammonium hydroxide, stir until there is cloudy nature. It shows that all the elements are now precipitated. Use/put 542 filter paper, in a funnel and put in 250ml flat bottomed flask. Wash several times with water, wash everything with warm, hot ammonium chloride and use NH_2SO_4 in the 250ml flask. Make up to mark the content up to 250ml flask. The content will be titrated for Ca and Mg (Ca indicator, Mg indicator are added for respective element required).

Allow content within the filter paper to be dried. Weigh an empty Platinum (P+) crucible. Put the 5.2 content residue, fire it in the furnace to 1,000°c or 1,200°c and heat at constant temperature for 1 hour, the R_2O_3 group.

Where $R^{'}$ = Fe, Ti. P, Mn.

For Ca.

Pipette 10ml into a conical flask, add 40mls of water and 10ml NaoH + 3mls NH_4OH hydroxy/+5 drops of cyanide (CN-) + a pinch of calcium indicator.

Titrate the content with bugger solution.

The titre values, if multiplied by some factors 2.804 - value of the calcium oxide (CaO).

For Mg.

10ml solution + 40mls of H_2O + N + Mg indicator

Titre value x 2.004 (factor) - MgO value,

R_2O_3 should be turned into solution.

Put a lump of pyrosulphate into the platimum cucible containing R_2O_3, heat on bunden burner, until the content melts and turn into solution.



Fig. IIa. Computation of Reserve estimate of Ironstone in Northwestern and Central area of Udubo (sheet 85).

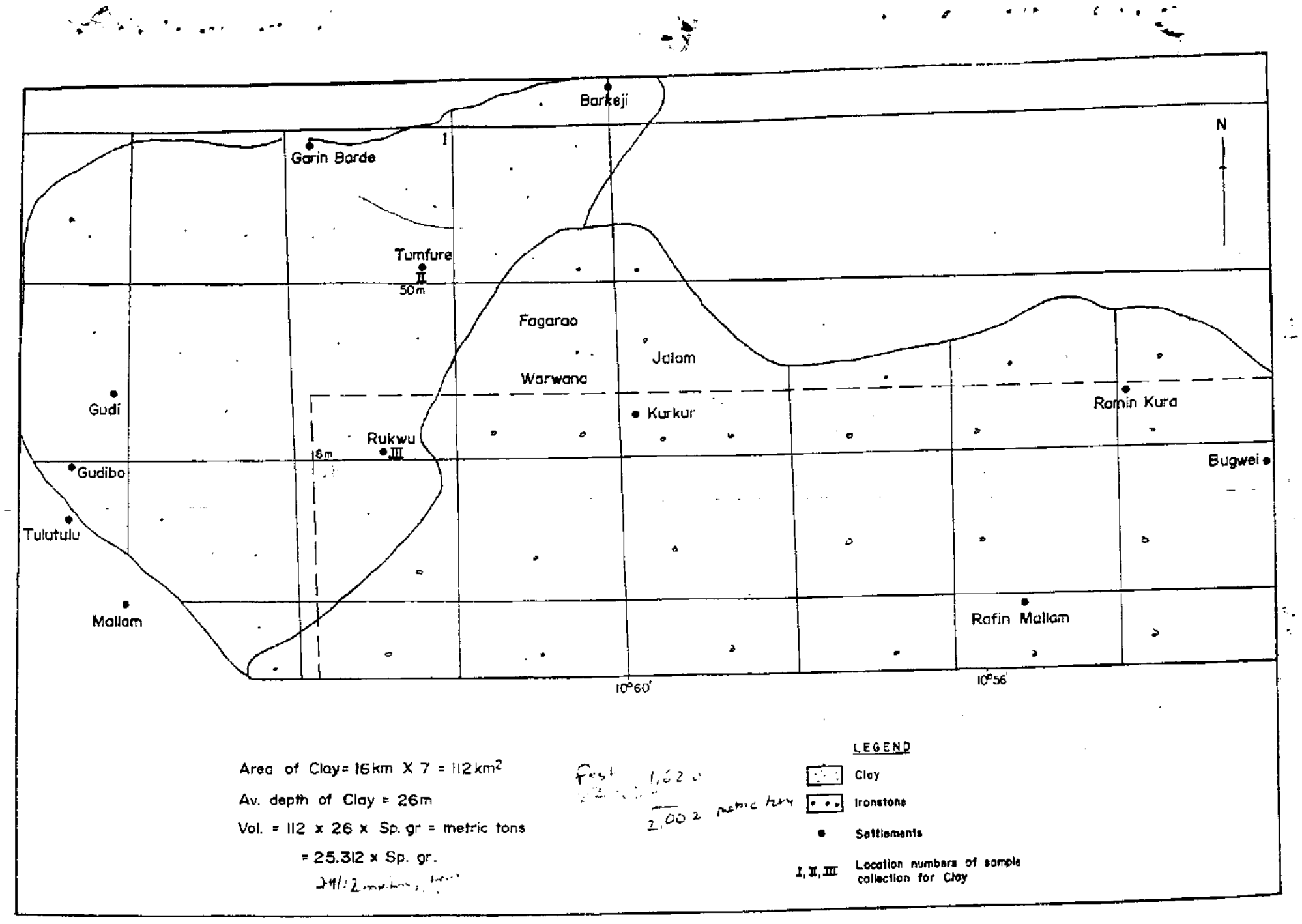


Fig. II.b. Computation of Reserve Estimate of Ironstone and Clay in One in Southern part.