GEOLOGY AND ECONOMIC MINERAL POTENTIALS OF PINDIGA, AKKO LOCAL GOVERNMENT AREA OF BAUCHI STATE.

By

Shaibu, Emmanuel Gabriel

THESIS PRESENTED TO THE DEPARTMENT OF GEOLOGY, ABUBAKAR TAFAWA BALEWA UNIVERSITY, BAUCHI, NIGERIA, IN PARTIAL FULFILMENT OF REQUIREMENTS FOR THE AWARD OF BACHELOR OF SCIENCE (B. SC) (HONOURS) DEGREE IN APPLIED GEOLOGY.

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DEDICATION

Dedicated to My Parents, Brothers and Sisters for endurance throughout my study.

ACKNOWLEDGEMENT

My special thanks go to my supervisors DR. D.M. ORAZULIKE and MR. A.W. MODE for their guidance, patience, persistent attention and all time encouragement throughout the period of this study.

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SHAIBU E.G.
JULY, 1989

ABSTRACT

The area in which this investigation was carried out is located between longitudes $10^{o}55'$ to $10^{o}55E$ and $11^{o}00'$ to $11^{o}00E$ and latitudes $9^{o}56'$ to $10^{o}02N$ and is drained by river Gongola. It covers about $99km^2$ in area. The area is underlain by sedimentary rocks. The rocks mapped in the area are:

a) Yolde formation

b) Pindiga Formation

c) Gombe Sandstone.

The oldest rock in the area is Yolde formation and is directly over lain by the Pindiga formation. The youngest rock in the area is Gombe Sandstone. The Yolde formation underlies 30% of the mapped area, the the Pindiga formation underlies 40% while Gombe Sandstone underlies the remaining 30%.

The Yolde Formation is coarse to fine-grained, the Pindiga formation contains bioturbated limestone towards the base and the Gombe Sandstone contains medium to coarse grained as well as ferruginised sandstone. It is brownish to redish in colour.

Economic mineral potentials investigated shows that there is a lot of potentials for limestone and gypsum especially along River channels around Pindiga.

The hydrogeology of the area is generally poor.

CONTENTS

PAGES

List of figures

LIST OF TABLES.

CHAPTER ONE

INTRODUCTION

1.1 AIMS OF THE PROJECT

The aim of this project is dual, firstly to produce the geological map of the area, showing major geological structures.

Secondly, it is aimed at assessing the possible occurrence of economic mineral deposits.

1.2. LOCATION AND ACCESSIBILITY

The mapped area is within the Akko S.E. sheet 151 and futuk N.E. sheet 172 both in the scale of 1:50,000 with about 60% of the mapped area in the former (i.e Akko S.E. sheet 151). These maps are among the topographic maps of Nigeria published by the Federal Survey department of Nigeria. The area lies in the Western part of Akko Local Government (Fig.1) and covers an ~~area~~ areal extent of 99 sq.k.m. It starts from a hill near Kashere and extends about Nine kilometers (9km) towards the West and eleven (11 km) towards the North. It lies within the longitude $10^{o}55'$ to $10^{o}55$E and 11.00 to $11^{o}00'$E and latitude $9^{o}56'$ to $10^{o}0_{2}'$N and $9^{o}56$ to $10^{o}02$N as shown in (fig 1) and enclosed geological map of the area.

The area is tranversed by Tum-Kashere road and is in Bauchi State of Nigeria. There are numerous minor roads and foot paths that lead especially to the Village for instance Sumbe.

1.3 RELIEF AND DRAINAGE

The area has a height elevation of approximately 1000m - 2000m above sea level. The major topographic features in the mapped area are concentrated in the South and South eastern parts. Nearly one quarter of the mapped area is hilly but rarely does the relief exceed 600m. The hills at sumbe, Garina Dawa are well drained. There is only one major river, that is River Pindiga with minor tributaries. The River runs from North east and flows towards the Southern part of the map. The River is seasonal, it contains water during dry season. It configurates and shows dendritic drainage pattern. It is V - shaped at the upper part and becomes U - shaped towards the lower part. The channel of the River becomes widened during the raining season due to increase in velocity and volume of the River. They are overbank floods in some parts of the mapped area.

1.4 CLIMATE AND VEGETATION

The climate of the area is the same as that of Bauchi, parts of Gongola, and Kano States. The area has two seasons in a year, a wet season and dry season. The wet season starts from mid-May to September and dry season starts from September till early May.

Within the dry season (from December to March) dry dusty North east (N.E.) trade winds from Sahara desert (locally called the hamattan) blow across the area, usually with low temperature (10°-15°C). The rainfall is mainly conventional type and the dry season is longer than the raining season. The annual rainfall in the area is between 6000mm-1000mm.

The vegetation depends on the climate. The area is deficient in tall trees. Generally, it has sparse vegetation with stunted trees, shrubs, grasses, thorny bushes which are commonly restricted to stream valleys.

1.5. PREVIOUS WORK

The earliest work was by J.D. Falcomer and A. Longbottom during the mineral survey of Nigeria (Falcomer 1911). Falcomer recognised the sediments of Cretaceous andeocene Ages.

Other works include that of Carter et al (1963). Carter et al affirmed that there is no record of Sedimentation in the long interval between Pre-Cambrian and late Mesozoic times. Record of Sedimentation, however, started in the Upper Cretaceous in two major Basins, the Chad and Benue Basins, separated by the Zambuk ridge. The oldest strata recorded are continental grits, sandstone and clays of Bima sandstone which are believed to be Aptian-Albian in age.

Nwajiide et al (1984) also worked on the origin of Benue trough and included sediments.

Popoff et al (1986), reinvestigated the exact age and Biostratigraphic subdivisions of Gongila and Pindiga Formations and the mutual relationship and paleontological implications.

Orazulike (1986, 1987) also worked on the economic mineral (Gypsum) potential around Pindiga in the Pindiga Formation.

1.6. SCOPE AND METHOD OF PRESENT INVESTIGATION

The method adopted during the field work was ground traversing which was purely done on foot. Stop-overs were made intermittently at stations where there were outcrops of rocks. Traverses were made along stream channels. Fresh samples were collected, observed with a handlens, described and put into the bag. Measurements of joint directions and other structures were carried out. In the laboratory, thin sections of these rocks were made and observed under the microscope.

Sedimentary samples were collected along stream channels. In the laboratory, the samples were sieved and analysed.

The instruments used for this work are, a geological hammer, a hand lens, a compass clino-meter and a bag for collecting samples.

CHAPTER TWO

2. DEPOSITIONAL HISTORY AND REGIONAL STRATIGRAPHY

The Oldest rocks in the region are remarks of ancient sedimentary series, probably of Pre-Cambrian age, Carter et al (1963). Sedimentation and metamorphism were followed by a cycle of orogenic granite enplacement during which the diverse older granites intruded and the ancient metasediments largely transversed into anatectic migmatites.

There was no record of sedimentation in the long interval between Pre-Cambrian and late Mesozoic times, Carter et al (1963). The actual record of sedimentation in the Upper Cretaceous in two major basins, the Chad and Benue Basins, separated by the Zambuk ridge. The oldest strata recorded are continental grits, sandstone and clays of Bima sandstone which are believed to be Aptian-Albian in age.

A widerspread marine transgression occurred during Late Albian - Cenomanian times and was exemplified in the Turonian by thick marine shales. This marine transgression was responsible for the deposition of the Yolde, Pindiga, Gongila and Fika shale Formations.

The marine deposition was followed by the Late Cretaceous episode and subsequent deposition of Gombe sandstone. The Kerri-kerri Formation was deposited in the Paleocene, this was followed by extensive laterite sheets.

Chad Formation was laid down in the Late Tertiary and Quaternary times and comprises lacustrine and alluvial-fluvial deposits.

THE STRATIGRAPHICAL SUCCESSION

			BENUE BASIN	ZAMBUK RIDGE GULANI AREA	GOMBE AREA	CHAD BASIN
Pleistocene						Chad Formation unconformity
Paleocene					Kerri kerri Formation unconformity	
Upper Cretaceous	Maestrichtian		Lamja Sandstone		Gombe Sandstone	
	Senonian	Campanian	Numanha Shales	Gulani Sandstone		
		Santonian	Sekule Formation		Fika Shales	
	Turonian	Upper	Jessu Formation	pindiga Formation	Gongila Formation	
		Lower	Dukul Formation			
	Cenomanian		Yolde Formation			
			Upper middle Lower	Bima Sandstone		
				unconformity		
L.Palaeozoic to Pre-Cambrian			Crystalline basement			

CHAPTER THREE

LOCAL STRATIGRAPHY AND PETROLOGY

3.1. INTRODUCTION

The mapped area consists of Yolde Formation, Pindiga Formation and Gombe Sandstone.

The Yolde Formation underlies 30% of the mapped area, the Pindiga Formation underlies 40% while Gombe sandstone underlies the remaining 30%.

3.2 YOLDE FORMATION

The Yolde Formation forms the oldest rock of the mapped area. The Formation is found to be transitional between the continental Bima sandstone and the succeeding marine Formation. Falconer (1911) recognised such a transitional Formation between Muri sandstone and marine Turonian and described it as the 'passage beds' other works, including Reyment (1965), described it as transition beds.

3.2.1. FIELD OCCURRENCE

The Yolde formation occupies the Southern part of the mapped area (see map). In the mapped area, it is directly overlain by the Pindiga Formation. The rocks in the Formation grades into the Pindiga Formation showing a transition boundary between both Formations.

3.2.2. PETROGRAPHY

In handspecimen, the rock is medium to - fine-grained and comprises mainly quartz and plagioclase.

In thin section (fig 2) it comprises of quartz (40%), Plagioclase (55%) by modal estimate. Accessory minerals are iron oxide and muscovite (5%).

Quartz (0.5-3mm in diameter), occurs as angular to subangular. The grains have irregular features and undulose extintion which suggests strain.

Plagioclase (2.4mm in length) occurs as tabular flakes with preferred dimensional orientation. It is pleochroic from green to brown, and shows extintion paralled to the cleavage direction.

Accessory minerals are iron-oxide and muscovite with the grain of iron (0.1-2mm in diameter).

3.3. <u>Pindiga Formation</u>

Pindiga Formation forms the older rock of the mapped area. The formation was first recognised by Barber, Tait and Thompson (1954) and suggested the names 'Calcarenite Beds' and 'Clay Shales'. These terms were recorded in lexigraphique stratigraphique International (1956).

Reyment (1956 p.10) used the term 'calcareous beds' for the lower part of this Formation. The Pindiga Formation is a sequence of marine shales and includes a number of lime-stones towards the base.

3.3.1 <u>FIELD OCCURRENCE</u>

The Pindiga Formation occupies the central part of the mapped area. It is directly overlain by the Gombe sandstone.

In the field, the formation consists of limestone, gypsum, shale, laterite or mud. This suceession marks the pindiga Formation type section observed along the Pindiga River. Where the succession is widely exposed, only the limestone and shale are observed. At Pindiga town the limestone are found scattered and laterites are widespread.

The type section was observed along the Pindiga River as follows:-

Locality 12

Lithology	Thickness (m)
Laterite	1
Shale	4
Limestone	2.3
Total thickness	7.3m

The colour of the Formation Varies according to lithology. The limestone and shale vary from grey to Pink in colour. The gypsum found in the area is mainly whitish to colour less. The laterite associated with the Formation is redish to darkish in colour. Erosion has greatly affected the area as limestones are sometimes seen mixed with gypsum.

3.3.2. PETROGRAPHY

In handspecimen the limestone contains mainly mud with thin wall mollusc. Laminations are conspicuously lacking. Bioturbation leading to removal of organic matter has reduced the colour of micrite to grey.

In thin section (Fig 3) it is mud supported. The mud is > 10% particles. Hence, it is referred to as Waekstone, (Dunham, 1962). Also present is micrite which contributes about 75% of the limestone. The dominant grains are ammonites and echinoid spines.

3.4. Gombe Sandstone

This lies directly above Pindiga Formation in the mapped area. This unit represents a return to a continental phase of deposition on the flank of Benue trough in the Late-Cretaceous. The basal beds are transitional clays and siltstone with rare coal layers. The upper horizon are either lenticular or isolated by subsequent erosion. This Formation is the top member of the Sedimentary sequence.

3.4.1 Field Occurrence

The Formation occurs at the Northern part of the mapped area. This Formation is directly underlain by the Pindiga Formation. The rocks in the area are found sometimes as boulders.

3.4.2 Petrography

In handspecimen the sandstone is medium to coarse-grained. It is ferruginised and contains some ironstones. It comprises of mainly quartz embedded in a finegrained groundmass of ironstone Feldspar is also present. The colour ranges from brownish to redish.

In thin section (fig 4), it comprises of quartz 75% feldspar 10% mica 2% and iron oxide matrix 13%. Muscovite which is present in small amount is colourless. It is seen bending around the quartz grains. Some of the quartz grains are rounded to sub-rounded with sizes ranging from 0.5m-3mm in diameter. It has a wavy extinction which is an evidence of strain.

Plagioclase (3.5-5mm length) is albite (An5 - 10) in composition and twining is according to albite Law.

Biotite (1-3mm length) occurs as tabular-subhedral grains and pleochroic from brown to dark brown with one directional cleavage.

It undergoes extinction parallel to the cleavage direction.

APPENDIX A

SIEVE ANALYSIS RESULTS FOR GOMBE SANDSTONE(FORMATION)

Sample No 1

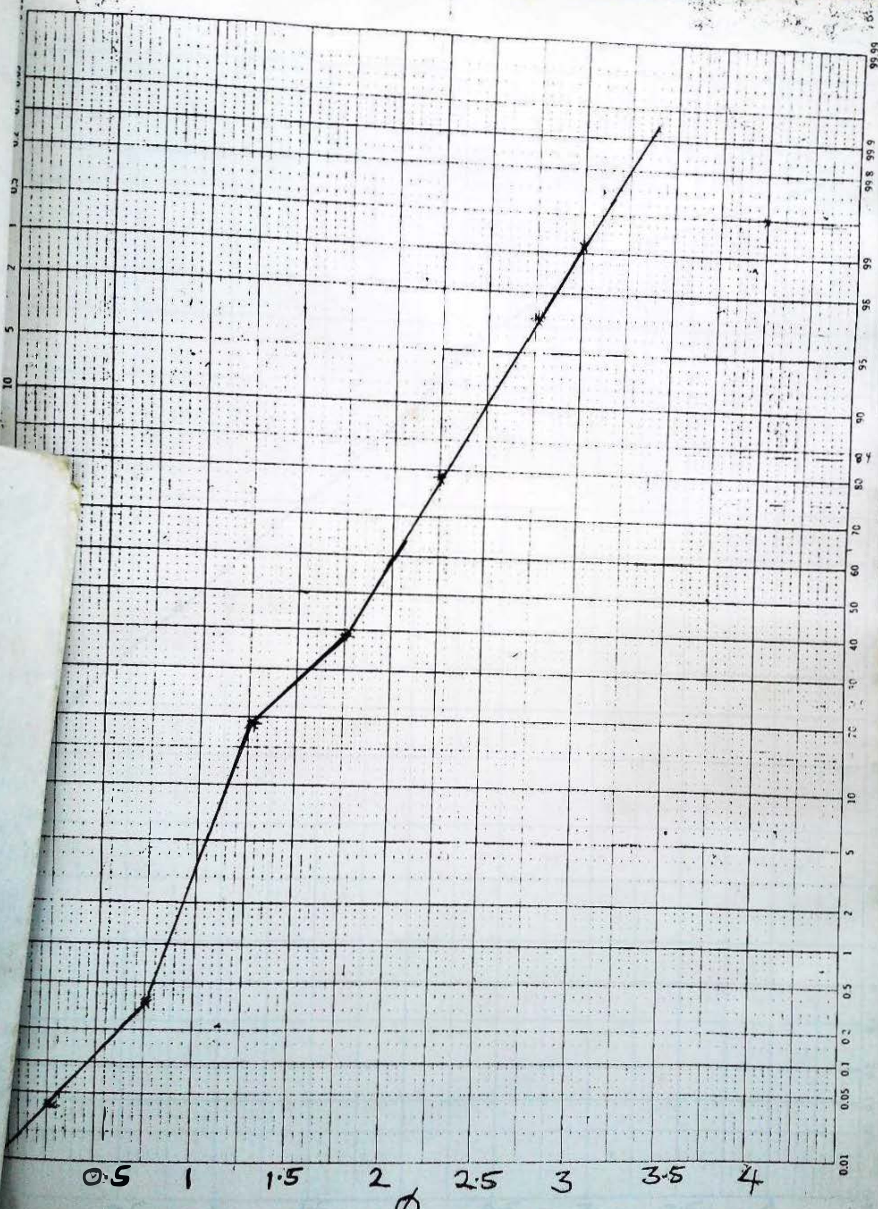
phi (Ø)	Weight	Cummulative Weight	Cummulative percentage
0.25	0.20	0.20	0.04
0.75	0.16	0.18	0.36
1.25	9.43	9.61	19.22
1.75	10.38	19.99	39.98
2.25	19.63	39.62	79.24
2.75	0.34	48.96	97.92
3.25	0.55	49.51	99.02
3.75	0.40	49.91	99.82
4.00	0.01	49.92	99.84
Pan	0.08 1	50.00	100.00

Sample 2

phi (Ø)	Weight	Cummulative weight	Cummulative percentage
0.25	7.4	15.28	32.48
0.75	9.01	18.02	50.50
1.25	12.33	24.66	75.16
1.75	7.10	14.20	89.36
2.25	3.27	6.20	95.90
2.75	1.55	3.10	99.00
3.25	0.27	0.54	99.54
4.00	0.22	0.42	99.82
Pan	0.20	50.0	100.00

Sample No.3

Phi (Ø)	Weight	Cummulative Weight	Cummulate Percentage
0.25	0.50	0.80	1.60
0.75	0.67	11.69	2.94
1.25	10.22	31.36	62.92
2.25	19.12	41.53	83.06
2.25	7.39	48.87	97.74
3.25	0.69	49.55	99.10
3.75	0.30	49.85	99.70
4.00	0.10	49.95	100.00
Pan	0.05	50.00	



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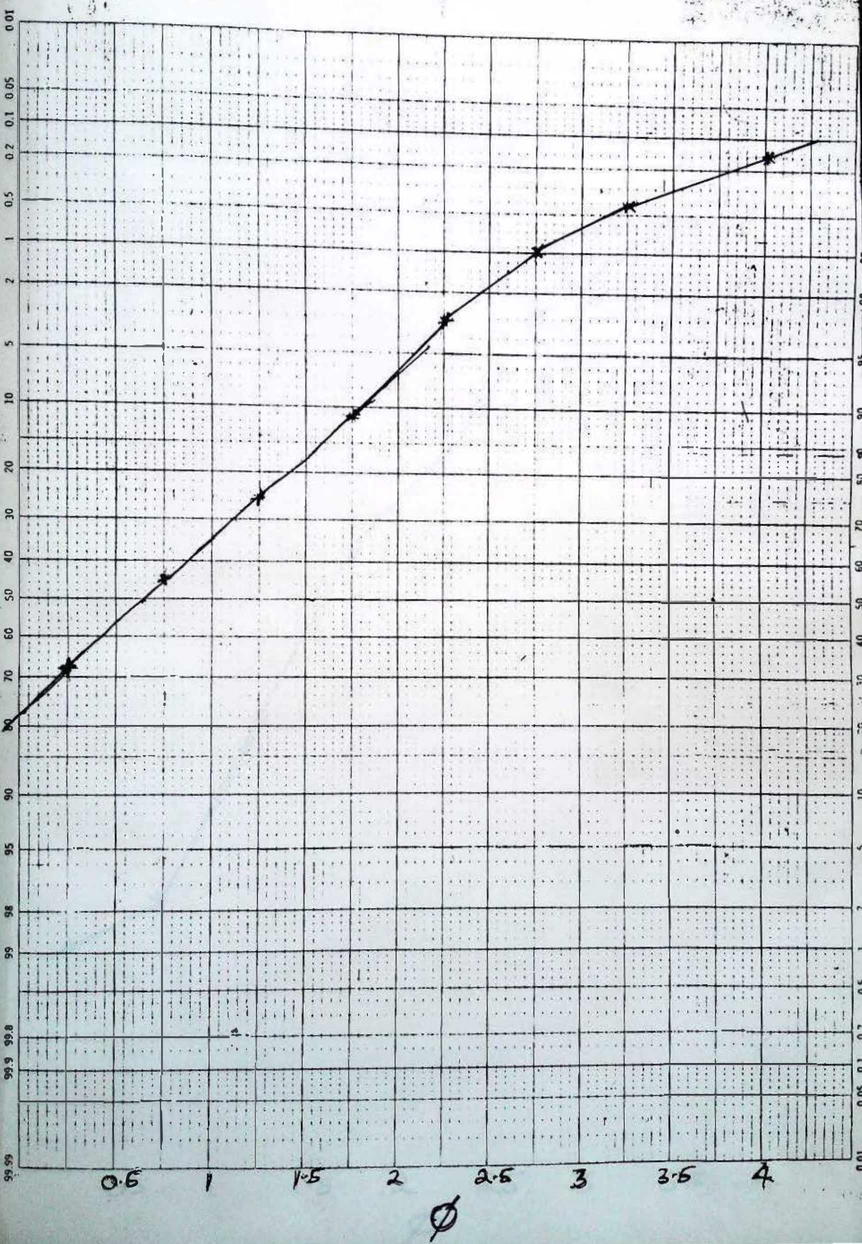
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CHAPTER FOUR

4. PINDIGA MINERAL POTENTIALS

4. 1. GENESIS OF MINERAL DEPOSITS

The formation of mineral deposits is complex. They are many types of deposits, generally containing several ore and gange minerals. Formation of mineral deposits involve the following (a) the source of the ore bearing fluids (b) the sources of the ore constituents (c) the migration of those ore bearing fluids and (d) the manner of deposition of the ore from deposits.

Their association with magma are due to internal processes on the otherhand those associated with sediments are due to surface processes.

4.1.1. MAGMATIC DEPOSITS

Magma from which minerals are formed is a silicate solution therefore it follows the law of aqueous solution. The minerals which are associated with magma can be formed as (a) magmatic segregation (b) Diseminated magmatic deposits (c) contact metasomatism deposits (c), pegmatite deposits (d) Hydrothermal deposits.

4.1.2. MAGMATIC SEGREGATION DEPOSITS

When magma cools and the saturation point is reached for any given mineral that mineral will crystallise out.

Magmatic segregation involves those minerals formed by settling of early formed minerals to the bottom of the magma when colling. Take for instance the formation of chromite, platinum find in Bush Veld igneous complexes and still water complexes in mantina are formed by magmatic.

4.1.3. DISEMINATED MAGMATIC DEPOSITS

This is formed by settling of immissible sulphide or oxide melt. They are part of magma and settle and do not form conspicuous layer instead, they form globles. The example of mineral formed in this way is magnetite bodies infected in faults as is in Norway. The CU-Ni sulphide of sudbury Canada belong to the layer sulphide.

4.1.4 CONTACT METASOMATIC DEPOSITS

This results particularly in the favourable of carbonate rocks. These are formed by replacing the wall rock of an intrusion by mineral whose component were derived from magma. Magnetite deposits of iron springs Utah is a good example.

4.1.5. PEGMATITE DEPOSITS

These are formed by filling features in the wall rock and consolidates in other part of intrusion. The pegmatite deposits are complex for instance the deposition of mica and rare earth deposits are good examples. The Uranium bearing pegmatite of Canada and Tin bearing pegmatite in younger grantes of Jos Plateau, Nigeria.

4.1.6. HYDROTHERMAL DEPOSITS

This is the deposit that results as near after the effects of magma consolidation. These are deposits from briming solution (salty). This kind of deposit occupies vens in the host rock or spaces of cooling magma. They may also be found by replacing host rocks. The good examples are the Pb-zn-cu deposits of the Mississippi Valley, Pb-zn deposit in Enyiba Abakaliki Benue trough and cu in the porphry copper deposits in Western U.S.A.

4.1.7. SEDIMENTARY DEPOSITS

Under condition of aridity, cut-off bodies of saline water undergo evaporation, which causes precipitations of the salines to form bedded deposits of common salt, gypsum, potash and latter substances called evaporites. The deposits formed mainly by precipitation of particular elements is synsedimentary, Deposits of concentration of heavy durable mineral as found in placer cassiterite deposits in Jos Plateau (Nigeria).

4.1.8. RESIDUAL DEPOSITS

These are formed by leading of soluble element and concentration of insoluble element in the residual material. For instance Nikeliferous laterite of News Calidonia, Bauxite (A1) ore of Arkansas U.S.A.

4.1.9. EVAPORITE DEPOSITS

This is an important group of chemical sediments. They are formed by the processes and results of evaporation. Both marine and lacustrine are common. Marine evaporites consist of over 3% of the total stratigraphic thickness of sedimentary rocks, and are known back to Precambrian. Lacustrine evaporites are wide spread in fault blocks and later deposited in mordern environments, Gulbet et al (1985).

Marine evaporites are formed in arid zones at or near continental margins. Evaporite sediments appear in the stratigraphic record along protorift zones where continental blocks have separated as at today's Read Sea. They are formed in foundered blocks with connection to the sea and in subsidiary basin that are part of that extensional protorift setting. They involve sea water flowing into land-lock basin along coastal margins, basins, which have no egress, with resultant evaporation of the seawater and continued concentration of the nonvolatite salts that remain as "distillation residue".

Lacustrine evaporites also require unusual tectonic regimes.

They appear to form either in extension fault blocks at high structural level or in topographic low in rain shallow deserts, ~~chapin et al (1981)~~.

Marine evaporites involve progressive solar distillation of seawater, the composition of seawater contrains the mineralogy and bulk composition of marine evaporites. The principal solution components are Na^{+}, K^{+}, Ca^{++}, Mg^{++}, Cl^{-} and SO_4^{2-}. Marine evaporites constitute the World's major source of salt, and thus of both Na and Cl; of gypsum, anhydrite, and of native sulfur biogenically generated from them. Also present are K, M_g, Br, I and of Rb and Sr, and other minor elements.

Lacustrine evaporites are more varied and contain evaporation - concentrated residue of waters which have raised and equiliberated with lithologically varied, generally arid terranes and "atomised or aerosol salts wafted in from distant marine coastal droplets in sea air or mists.

Gypsum is formed mainly in sedimentary enviroments specifically in marine enviroment as it can be seen from above. It is among the evaporite minerals which occur mainly as a result of evaporation of saline resulting in sea saline residue of the enclosed basin. Gypsum also occurs as a result of precipitation from the host rock. It can be either be syngenetic or postgenetic.

4.2. GYPSUM OCCURRENCE IN BAUCHI STATE

INTRODUCTION: Nigeria is blessed with many mineral resources. Among the proven mineral resources of Nigeria are oil and gas, coal, lead , and Zinc deposits, all in the Southern parts of the country. Tin and Columbite, niobium are in the central parts of the country. Others are industrial minerals such as limestone, asbestos., phosphates and many less known others such as gypsum, all scattered throughout the country. Exploration for economic mineral potentials are going on in different parts of the country today by the Geological Survey of Nigeria. There are potentials for occurrence of Gold in Madaka (Niger State) and some parts of Sokoto and Bendel in (Imo State).

The mineral resources of any locality is governed by the number of mineral deposits that can be defined by as ore. To this end, the determining factors for a deposits to be ore include availability of the mineral in large quantities, market price of the mineral which include turn depends on demand, cost of mining and processing, transportation, environmental impact of mining and polities. While granting that the economics of mineral recovery is a strong factor in mineral availability the overriding factors are geologic. Therefore, gypsum occurrence must be recognised as geologic phenomenon,

(a) Geographical distribution of potential ore minerals concentration.

(b) Depth of these concentration the crust.

(c) Mineralogy and grain size of the ore.

(d) Grade and turnages of the concentration.

(e) Mode of occurrence of the mineral.

For mineral deposit of any type in any geologic entity or political environment, the lowest cost metal will tend to be produced first. This trend is logical and follows the economic mineral exploration and exploitation whereby the largest deposits tends to be found first. Hence, gypsum that have the mineralogy and grain sizes that are relatively cheap to process will be developed and produced first. The small, apparent main economic deposits seldom are present in adequate size. These, then, are invariably omitted and discovery must require extra effort, extra cost geologic investigation and scientific known-how and dedicated geoscientist. This is most true of gypsum occurrence in Nigeria, especially these occurrence in Bauchi State.

4.2.1. GYPSUM OCCURRENCE IN NIGERIA ESPECIALLY IN BAUCHI STATE.

A great majority of the metallic mineral resources now available were discovered by accidents having been virtually stubled upon.

Gypsum is found occuring in different sedimentary basins in Nigeria. It has been found scattered in crystal intertiary clays in Onitsha province, and in Cretaceous sediments in Benue Valley and Sokoto. It has also been found in Chad Formation in Borno, mineral and Industry in Nigeria, Raeburn (1948).

Gypsum occurs in Bauchi State in Fika Shale and Pindiga Formation. The latter Formation is in the South and gypsum in it grades into the Former towards the North (fig.5) In the former Formation, Gypsum occurs at Mada and Gadaka, but the occurrence in the latter formation is restricted to Pindiga and has been reported by cater et al (1963) and has been investigated recently by Orazulike (Orazulike 1986,1987).

At Mada and Gadaka all in Turonian Fika shale Gypsum occurs as seams 2cm-10cm think as six seams within a ½ meter sequence of shale/clay rocks (Fika shale) in a pit about ½ meters deep was counted at Mada. At Gadaka, gypsum seams occur at a break of slope with only a few centimeters of top soil above it. In this locality, the commodity also occurs along stream channels and gullies. In Mada seams can be traced over 2.3 meters distance and at a depth of 1½-2 meters. More seams are likely to occur at greater depth, Carter et al (1963).

At Pindiga (in Pindiga Formation) Gypsum occurs as seams along stream channels especially towards the South eastern part of the Pindiga river. This also forms part of the type section of the Pindiga Formation (Plate 4).

It also forms along gullies Souths east of Pindiga town. In Pindiga seams can be traced over 3-4km distance and at a depth of over 1-2 meters. It is ob obvious that more seams are likely to occur at greater depth.

4.2.2. GYPSUM COMPOSITION, MODES OF OCCURRENCE AND USES

4.2.2.1 COMPOSITION: Hydrated calcium sulphate $CaSO_4$ $2H_2O$ (commonest of all sulphate minerals). The percentage composition of the elements that make up the Gypsum are as follows:-
$Ca = 32.6\%$ $SO_3 = 46.5\%$, $H_2O = 20.9\%$
Robert et al (1931)sand clay and organic matter occur as impurities in Gypsum.

4.2.2.2 MODES OF OCCURRENCE: Cypsum occurs abundantly and widespread chiefly in sedimentary deposits, especially in permian and triassic formations, in saline lakes and playas as efflorescent on certain oils, in oxidised portion of ore deposits, and indeposits associated with limestone, sandstone, dolomite shales and salt beds.

Gypsum is formed in three chief ways. It can be formed thus:-

1. as a saline residue arising by the evaporation of enclosed basin of seawater, as stassfont in German, Robert et al (1931)
2. accompanying the dolomitization of limestone in the sea, Robert et al (1931)
3. by the formation of a calcium sulphate along with

sulphuric acid, generated the decomposition of pyrite, or calcium suplphate carbonate of shells etc in clay the good crystal of selenite found in many formation of such, such as the London clay Oxford, Robert et al (1931)

4.2.2.3 USES: Gypsum is an important industrial mineral over 42 million tons (including some anhydrite being produced in 1959. Robert et al (1931).

The chief producers are U.S.A. Canada, Britain, France, USSR, Span, Italy and Germany, Britains annual production is well over 4 million tons. It is used in building industries, used as retarder in Portland cement. In this case, cement is manufactured by mixing about 80% limestone, 17% shale or clay and 3% iron III oxide. The mixture is then heated to about 1500°C in a furnace thus, driving of CO_2 and H_2O. The mixture then fuses. When this motten mixture cools, it solidifies into a clinker. This is then mixed with 3%-6% Gypsum which supply sulphide to retard the settling of time of cement. It is also used as a filter in various material, such as paper crayon, paints, rubber etc. and in the manufacture of plaster of paris inform of $CaSO_4$. calcium gypsum is extensively employed in the building trade, forstuce work, it is also used as polishing beds in the -

Calcined gypsum is used for industrial plasters, such as those used in pottery, molding dentistry, and stationary. Pure white uncalcined gypsum known as terra-alba is used as a filler in paper and paints, as materials in growing yeast. Other uncalcined gypsum is used as filler in insecticide.

Gypsum Varities selenite includes crystallized form of gypsum.

Alabasta is a very fine grained and compact snow-white or light - coloured massive variety.

Satine-spar: This is the fibrous variety and has a silky lustre

Gypsite is gypsum mixed with sand and dirt.

Colour: Crystal colourless, massive varieties. colourless or white, sometimes grey, yellowlish or red.

4.3. PINDIGA GYPSUM ANALYSIS

METHOD OF STUDY

The Pindiga gypsum analysis were carried out using XRF and DCP or ICPMS techniques. The constituents measured as oxides are calcium (Ca), Florine (F), Potassium (K), Aluminum (Al) and Silicon (Si) and were expressed in percentage using XRF method. The impurities analysis were carried out using DCP or ICPMS techniques.

4.3.2. RESULTS:

The chemical analysis of the Pindiga gypsum in the two different samples examined are as shown in Table 1. The complete XRF analysis of sample No.1. is as shown in table 2 with included impurities.

4.3.3. COMPOSITION

The composition of the Pindiga gypsum is as shown in table 1. The gypsum composition is (82.42-89.11)% $CaSO_4 \cdot 2H_2O$. This shows that the gypsum is a pure variety since it falls within the range of 85-90% shown to be pure and of commerical value.

All other oxides found such as $CaSO_4$, $CaCO_2$ SiO_2 are impurities. The anhydrite ($CaSO_4$) ranges from 6.00-2.48)% and SiO_2 which is next in higher amount to gypsum in the two analysis ranges from 6.85 - 13.85% as shown in table 1. These impurities are negligible and do not affect purity of the its occurrence with gypsum at sampling site.

In the two analysis, the percentage of CaO(lime) is high so also sulphide (SO_3). This signifies the higher amount of gypsum and hence its purity.

In the complete XRF analysis, the CaO found is of higher percentage. It is 31.70 showing the evidence of pure gypsum is from line. The line also serves as important industrial mineral. This complete XRF analysis has some trace elements as impurities. These impurities are perhaps derived from the host rocks.
Table 2 shows the elements precipitated with gypsum.

The gypsum composition is good since it is within the composition used commercially.

4.3.4 GENETIC MODEL

The gypsum seems to have been precipitated from the host rocks(shale and limestone) as a result of meteoric water which percolates into the rock and therefore gried a higher amount of SO_4^{2-} (6.09 table 3). As it could be seen in the field, the gypsum is ~~seen~~ sandwiched between the host rocks. The gypsum is found as shown in fig.6 and ~~plates~~ plate 1 .

It developed fibres as it could be in the diagram in figure 6.

The gypsum fills in the fracture and it expands as it occurs in seqms. This is an open filling texture. Although gypsum can be found as evaporites, the one found at pindiga is as a result of precipitation from the host rocks. It therefore lies between the two host rocks. The pindiga gypsum formed in a manner is a postgenetic deposit.

In the field it is seen to occur as parallel bedding plate 2. In some other locations it is seen cutting across bedding plate 3.

4.3.5 ECONOMIC ASPECTS

Pure gypsum every where is found as fluxing. However, we do not know the reserve of the pindiga gypsum. For rhe gypsum to be economically viable, it must be laterally extensive.

All one can tell about the Pindiga gypsum is that it occurs in seqms. Since the pindiga gypsum is of chemical quantity required for commercial use, future work in the area should lay emphasis on the extent of the gypsum. To the rapid growing cement industries in Nigeria, the Pindiga gypsum if adequately given attention will serve as alternative to the shortage of raw materials for cement.

The Gypsum reserves could be demonstrated as shown below.

IDENTIFIED GYPSUM RESOURCE

Economically and legally feasible = Gypsum Reserves	Not Economically and/ or legally feasible = Sub economic gypsum Resource

Undiscovered Gypsum Resource
(Existence not Demonstrated)

NAME OF SAMPLE No.1 FROM STREAM CHANNEL CHANNEL (FINDIGA)		NAME OF SAMPLE NO.2 FROM STREAM CHANNEL (FINDIGA)	
Oxide	Percentage	Oxide	Percentage
$CaSO_4.2H_2O$	89.11	$CaSO_4 2H_2O$	82.42
$CaSO_4$	2.48	$CaSO_4$	0.00
$CaCO_3$	0.00	$CaCO_3$	0.42
M_gCO_3	0.42	M_gCO_3	0.00
SiO_2	6.85	SiO_2	13.85
Al_2O_3	0.67	Al_2O_3	1.80
Fe_2O_3	0.16	Fe_2O_3	0.22
Na_2O	Not determined	Na_2O	Not determined
K_2O	"	K_2O	"
undetermined	0.31	undetermined	1.29
Total	100 .00	Total	100.00

Combined water (H_2O)	18.65	Combined water (H_2O)	17.25
Moisture (H_2O)	0.83	Moisture(H_2O)	1.25
CO_2	2.48	CO_2	4.26
CaO	26.98	CaO	24.87
SO_3	42.91	SO_3	33.88

TABLE 1

Complete XRF analysis : Gypsum No.1 (Pindiga)

Oxide	Percentage (%)
SiO_2	6.07
Al_2O_3	2.06
CaO	31.70
MgO	0.45
Na_2O	0.01
K_2O	0.22
Fe_2O_3	1.16
MnO	Tr
TiO_2	0.08
P_2O_5	0.17
Total	63.50

Impurities in PPM

Rb	21
Sr	207
Y	11
Zr	10
Nb	10
Ba	27
Pb	6
Zn	16
Mn	16
V	20
Cr	26

TABLE 2.

WATER FROM PINDIGA BOREHOLE
PH = 9.24

Constituent	Mg/C
HCO_3^-	524
SO_4^{2-}	6.09
Cl^-	ND
F^-	2.04
NO_3^-	1.17
CO^{2-}	58.00
Total	591.30

Table 3

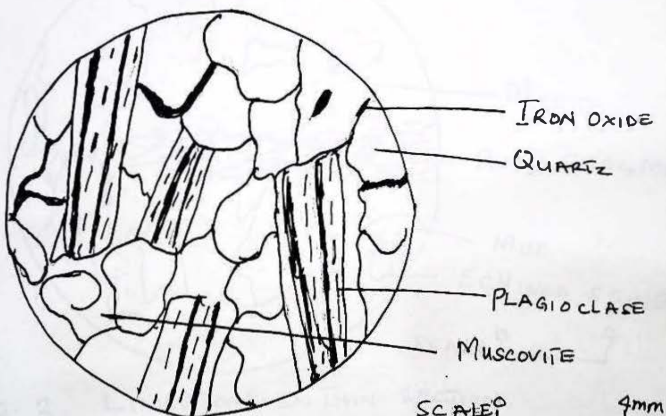


FIG 2. SAND STONE IN THIN SECTION.

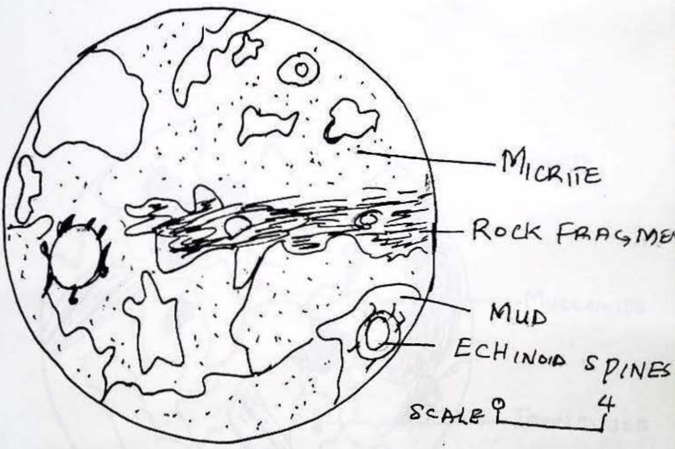


FIG. 3 LIMESTONE IN THIN SECTION.

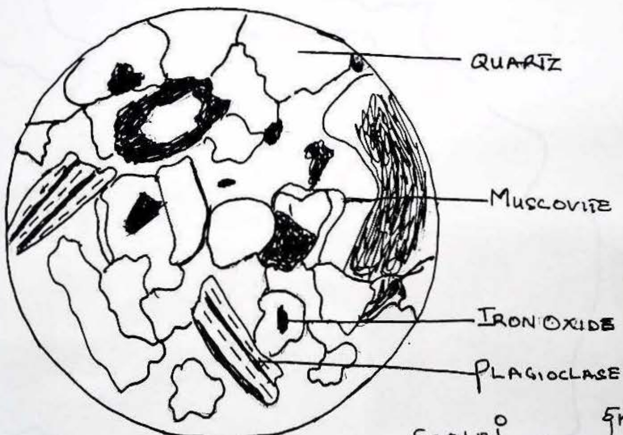


FIG 4 SANDSTONE IN THIN SECTION.

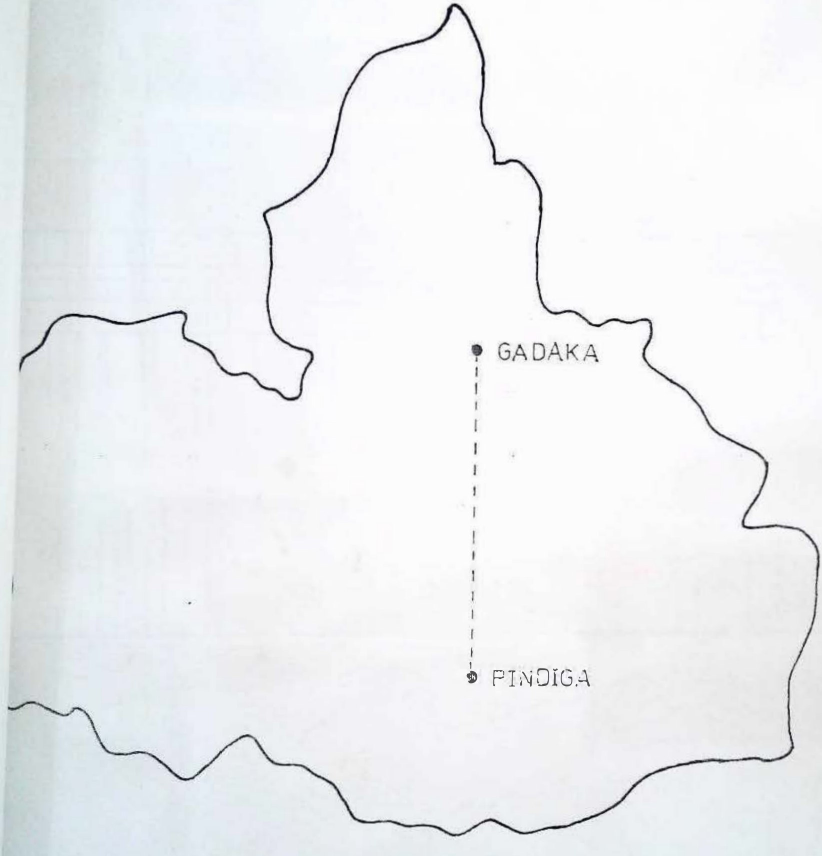


FIG. 5 MAP OF BAUCHI SHOWING GYPSUM TREND FROM PINDIGA TO GADAKA.

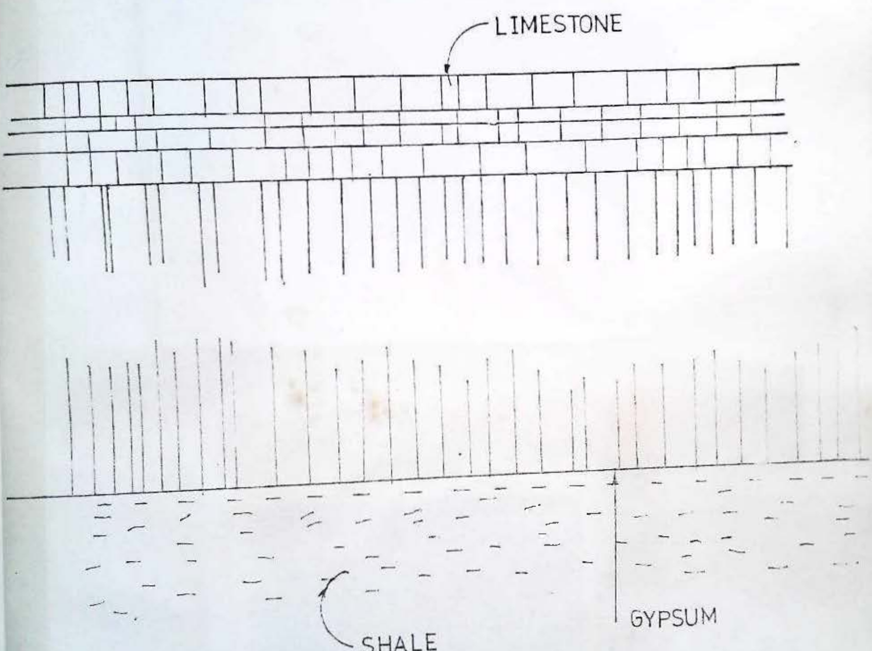
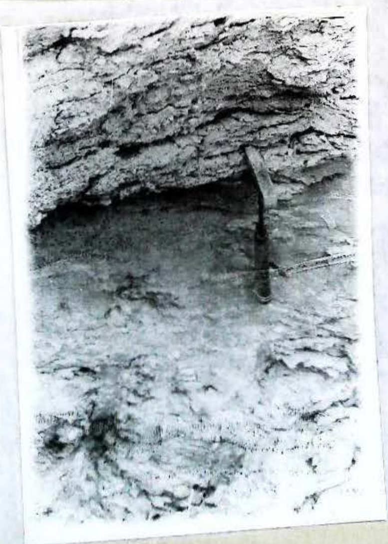


FIG. 6 GYPSUM SANDWICHED BETWEEN THE HOST ROCKS.

PLATE 1. GYPSUM SANDWICHED BETWEEN THE HOST ROCKS.



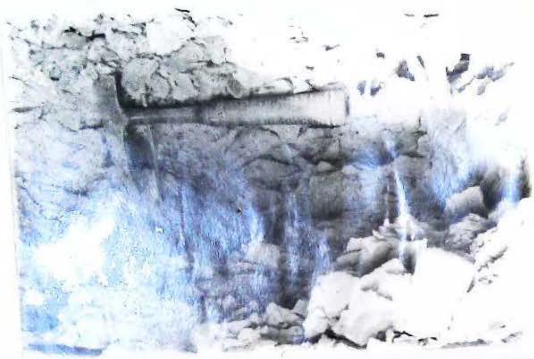


PLATE 3. PINDIGA GYPSUM SEEN CUTTING ACROSS BEDDING.

CHAPTER FIVE

ECONOMIC GEOLOGY AND HYDROGEOLOGY

5.1. Economic Ceology

The main economic deposits found in the mapped area include limestone, Cypsum, clay minerals, Alluvium deposits, stream sand and laterites.

The limestone occurs in the area and are used as loose slabs and blocks all over the surface of the ground especially along River Pindiga where the type section of the Pindiga Formation occurs. No detailed investigation of the limestone has been carried out through reserve appears to be substantial. At Kamawa, limestone of the Pindiga Formation has been burnt in tow small kilms by Gombe Native Authority for many years. Drilling has however, shown that no useful reserves of the limestone are present at this locality. The limestone surface debris at Kamawa and Pindiga is quite suitable as a source of lime for building or agriculture and minimum of 75,000 tons of limestone is available at or within a foot of the ground surface in these areas.

The Gypsum found in the area also serves as a source of raw material for cement. It contributes about 4% of the total raw material for making cement.

The laterite of the Gombe Formation found in the area serves as road - surfacing material. The laterite especially Oolitic ironstones are used in the production of iron ore.

The clay minerals include illites and montmorillonites deserved from intensive weathering were deposited away from active current in quite basinal condition that are obtained during the deposition of Pindiga shales. The clay deposit is used for clay brick factory.

The Alluvium deposit scattered all over the mapped area are watered during the raining season and thus making it suitable for the plating of maize, millet, potatoes, tomatoes, Even during the dry season, crops are grown on the alluvium deposits on the bank of the Pindiga River by the practice of irrigation system.

The sands along the channels of the Pindiga River are constantly gathered and transported using tippers to areas where they are used for building purposes. Sands are mixed with cement in the production of block cement. The mixture is used for plasting and chocking blocks during building of houses. Sands also can be used for glass industry.

Laterites found in the area especially the oolitic ironstone can be used for production of iron ore.

5.2. Hydrogeology

Streams and Rivers in the mapped area are dried up during the dry season. Because of this, there is shortage of water, mainly during dry season. At this time, the water levels go down and for the inhabitants to get water for use, they have to dig into the earth untill the water level is met.

In fracture rocks, water are infiltrated into the cracks and fracture, where they are trapped.

The water can be extracted after a well has been dug into this zone. Almost all the hard dug wells scattered in the area of alluvium deposits. The wells are shallow and their depths vary from one place to another. The depth ranges from 4m and above during the dry season. During the raining season, the water level rises and water can be struck after digging at a depth of about 3m or below. During the dry season, wells, dug below 3m proved to be unproductive.

The wells in the area have been recommended since there is no other alternative source of water supply. Moreover they are cleaner than the surface water from the Pindiga River. Efforts to drill for deep wells in the area has proved abortive. Depth of about 30m has been drilled at the Government Secondary School Pindiga but this has little yield.

The main source of water re-charge in this area is rainfall.

CONCLUSION AND RECOMMENDATION

The area in which this project was carried out is underlain by Yolde Formation, Pindiga Formation and Gombe sandstone. The Yolde Formation consists of medium to fine grained calcareous sandstone. The Pindiga Formation forms the bulk of limestone and gypsum in the area. The limestone found in the area are of Waekstone type and the gypsum of pure variety. The Gombe sandstone comprises of mainly quartz, feldspar and some acessory minerals such as biotite.

The project has given the geologic outline of the area and the potentials for mineral deposits. In the course of the project, assumptions have been made some ~~and~~ tentative ideas have been put forward. It is therefore recommended that extensive geological work be carried out in the area. This may help in solving the riddle in the age relationship between the limestone found in the area and the gypsum.

Also grain size analysis should be done with 16 or more samples to shed more light or free. environment of deposition.

It is also recommended that detail research on the economic mineral potential of the area be carried out to see if our non-economic gypsum resource could be gypsum reserve

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