NASARAWA STATE UNIVERSITY, KEFFI, NIGERIA.

Inaugural
Lectures Series
Volume 1

Edited by
G.S. Omachonu

Printed By:
Eiwa Press Ltd. Jos Plateau State, Nigeria.
+234-083-553-6267
eiwapress@yahoo.com

Edited by:
G. S. Omachonu

ISBN: 978-978-49183-4-3

Preface

An inaugural lecture, even from its very beginning at the University of Oxford, England where it originated as far back as 1623 (Omole as cited in Folorunso 2016:9), is meant to serve, at least, three major but purely academic purposes: (1) an account of the professor's stewardship in the academia and to inform the audience of the essence of his/her work to date, including current research, (2) stating his/her future plans especially the scheme of research which the professor proposes to do while occupying the chair, and (3) to talk about the state of the discipline; charting its progress, discussing its current health and problems, as well as examining its intellectual outputs which justify its inclusion in the university academic curriculum.

In line with the tradition, an inaugural lecture is a public presentation at which the professor is expected to tell the world what he/she professes in a language that is devoid of professional jargons and esoteric registers. The simplicity of language is important because an inaugural lecture provides the professor with the opportunity to address three blocks of audience simultaneously: his/her professional colleagues, the entire university community and the general public. With eighteen (18) of such lectures in a series in our university, one can attest or speak of an established tradition of inaugural lectures in Nasarawa State University, Keffi. The contribution(s) of each of the lectures is clear but the decision to edit into volumes (ten lectures in one volume), is informed by the desire to preserve the pieces of information contained in the lectures in one piece for unity of purpose, uniformity of preservation format and best practices. It is to allow the pieces of information to hang together rather than hanging separately; the more the merrier.

Of the eighteen (18) inaugural lectures presented so far in the series, this volume contains the first ten lectures in the series comprising three from the Faculty of Agriculture, two from Arts, another two from the Faculty of Natural and Applied Sciences, and one each from the faculties of Administration, Environmental Science and Social Sciences. These are inaugural lectures presented from 26th March, 2008 when the first of such lectures in the university entitled 'Soil Husbandry: Lifeline for National Food Security and Economic Empowerment' was presented by Prof. Olusola O. Agbede of the Faculty of Agriculture to 18th November, 2015 when the tenth Inaugural Lecture was presented by Prof. Folorunso A. Ajayi of the same faculty.

Agbede's lecture which is the first both in the series and in this volume, concerns itself with how our soils must be carefully and wisely used to attain food security in Nigeria. The second in the series and in the volume was presented by Prof. Obaje of the Faculty of Natural and Applied Sciences. Obaje's lecture entitled 'Geology and Mineral Resources of Nigeria: Development Options for Economic Growth and Social Transformation' (13th August, 2008) presents options that will enhance optimal exploitation of the mineral resource wealth of the nation for its economic growth and socio-political transformation. 'Before we Set the House Ablaze: Let Us Consult Our Oracle (History)' presented by Prof. Olayemi Akinwumi of the Faculty of Arts on 11th December, 2009 is the third in the series. It was an eye-opener to the fact that if Nigeria is to be truly a great nation, we must go back to our sense of history; for the nation suffers which has no sense of history. This was followed by the fourth, 'Farm Production Efficiency: The Scale of Success in Agriculture' by Prof. Abdul Rahman of the Faculty of Agriculture presented on 26th June, 2013. Its major preoccupation was to describe farm as a system that produces agricultural commodities under certain restrictions as well as the interrelated factors that determine success in the entire agricultural sector of the national economy. The fifth in the series and in this maiden edition was MAINOMA (Most Acceptable Index Needed of Measuring Accountability) presented by Prof. Mainoma of the Faculty of Administration on 8th January, 2014. It seeks to provide the most acceptable model or index for measuring accountability.

'Researching Criminal Justice and Security Administration in Nigeria: Issues, Challenges and Opportunities' is the sixth in the series. It was presented on the 12th March, 2014 by Prof. Sam O. Smah of the Faculty of Social Sciences. The focus of the lecture was to draw attention to the fact that inaccuracy of available data due to lack of expertise by statistical officers, weak or poorly framed information gathering techniques and instruments, poor documentation attitude, inadequate analysis and storage are the banes of effective and efficient criminal justice and security administration in Nigeria. The seventh and eighth in the series were presented by Prof. Kwon-Ndung of Natural and Applied Sciences and Prof. Zaynab Alkali of the Faculty of Arts on the 17th September, 2014 and 17th December, 2014 respectively. Whereas the former shows how the presenter's research works in Plant Genetics and Breeding have contributed in the search for national and global food security, the latter dwells on the relevance of Gender Studies in Nigeria's Higher Institutions of Learning. The ninth Inaugural Lecture entitled 'Habitats and our Habits, Ecological Community and Common Unity' was presented by Prof. H. K. Ayuba on the 22nd April, 2015. It draws attention to the manifestations of unfolding economic, social and environmental catastrophes, which were largely due to pressures from human activities and economic necessities. It suggests a paradigm shift towards sustainable environmental management. The tenth in the series and the last in this volume was presented on 18th November, 2015 by Prof. Ajayi of the Faculty of Agriculture. The lecture entitled 'Insects, Plants and Humanity: The Organic Agriculture and Stored Products Protection Axis' is essentially an overview of the interplay between man and insects, highlighting that much of the crop harvests are lost to obnoxious insect pests during storage. It enunciates the factors that can enhance food security through better management of postharvest losses, propagating the use of traditional plant products as a means of protecting stored produce. In all, the divergent views and the varying thematic preoccupations of the lectures notwithstanding, one is left with the impression that though celebrations may vary from one place to another, true politeness is everywhere the same. In other words, methodology and approaches may vary but truly good scientific research is so recognized in every discipline.

Editing inaugural lectures which appear somewhat like finished products from seasoned professors who are authorities in their own rights was a daunting task. What we did was more of language editing to minimise grammatical and typo errors wherever found.

Even as it is, we do not guarantee uniformity in styles of content presentation and referencing but we have done the best that is possible given the circumstance in which we have found ourselves. I wish to thank all who had assisted in one way or the other in the editing and/or proofreading of the manuscripts.

I wish to use this medium to thank the Vice-Chancellor of our great university, Prof. M. A. Mainoma, and his Management Team for the all-round support and encouragement we have received from them since we came on board as the University Inaugural Lecture Committee, especially the provision of the fund for this publication. I thank the Inaugural Lecturers whose lectures have been published in this maiden edition of the NSUK Inaugural Lectures Series for the permission to do so. Congratulations! I thank the Information and Protocol Unit under the leadership of Abraham Ekpo who had been very helpful in organizing the University Inaugural Lectures Series. Thank you all.

Prof. G. S. Omachonu, PhD, FAvH, FICSHER
Editor/Chairman, Inaugural Lectures Committee
Keffi, 3rd July, 2018.

Foreword

Nasarawa State University, Keffi is known for upholding core University Academic Traditions, one of which is the Inaugural Lectures series. As many of us are aware, inaugural lecture provides an academic an opportunity to tell the world what he professes. It is a moment to celebrate excellence and breakthroughs with family, friends and colleagues. It is a testimony of one's contribution to the body of knowledge and his identification of his own building blocks in the system. It also affords the larger society opportunity to know researches that were carried out, those ongoing and the future plans. It also provides an opportunity to share with the audience how he/she used the knowledge of his/her chosen profession to advance the cause of the society especially in problem solving. To my mind, besides their contributions to knowledge, what Professors in NSUK have done thus far, presenting their inaugural lectures, is to really address societal problems using the insights and knowledge from their respective disciplines or professions.

The Nasarawa State University, Keffi Inaugural Lecture series Vol. 1 presents an opportunity to put together the first 10 inaugural lectures that were presented in the University. These are:

S/N	Presenter	Title of Lecture	Date
1	Prof. Olushola O. Agbede, Professor of Soil Science	Soil Husbandry: Lifeline for National Food Security and Economic Empowerment.	26th March, 2008
2	Prof. Nuhu G. Obaje, Professor of Geology	Geology and Mineral Resources of Nigeria: Development Option for Economic Growth and Social Transformation.	2nd February, 2009
3	Prof. Olayemi D. Akinwumi, Professor of Inter-Group Relations	Before we Set the House Ablaze, Let's Consult the Oracle (History)	11th December, 2013
4	Prof. Shehu Abdul Rahman, Professor of Agricultural Economics & Extension	Farm Production Efficiency: The Scale of Success in Agriculture.	26th June, 2013
5	Prof. Muhammad Akaro Mainoma, Professor of Accounting and Finance	Most Acceptable Index Needed Of Measuring Accounting (MAINOMA)	8th January, 2013
6	Prof. Sam O. Smah, Professor of Criminology Studies	Researching Criminal Justice and Security Administration in Nigeria: Issues, Challenges and Opportunities.	12th March, 2014

7	Prof. Emmanuel Hala Kwan-Ndung, Professor of Plant Genetics and Breeding	Unlocking Genetic in Search of Food Security	17th September, 2014
8	Prof. Zaynab Alkali, Professor of Literature and Literary Studies	The Relevance of Gender Studies in Nigeria's Higher Institutions of Learning: Why Gender Studies?	17th December, 2014
9	Prof. Haruna Kuje Ayuba, Professor of Biogeography and Environmental Science	Habitat and our Habits, Ecological Community and Common Unity	22nd April, 2015
10	Prof. Folorunso Abiodun Ajayi, Professor of Agricultural Entomology/Crop Protection	Insects, Plants and Humanity: The Organic Agriculture and Stored Products Protection Axis	18th November, 2015

This publication is intended to provide easy reference material to the academic community, policy makers and the general public. It is hoped that we shall continue with this tradition with subsequent editions.

While congratulating those that are part of this publication, I recommend this publication, to the professional colleagues of the inaugural lecturers, University community, policy makers and the general public.

Professor M. A. Mainoma
Vice-Chancellor

Table of Contents

2

GEOLOGY AND MINERAL RESOURCES OF NIGERIA: DEVELOPMENT OPTIONS FOR ECONOMIC GROWTH AND SOCIAL TRANSFORMATION

Professor Nuhu George OBAJE

B.Sc (ABU, 1984), M.Sc (ABU, 1987), Ph.D. (Tuebingen, Germany, 1994)
Royal Society Fellow (Aberdeen, 1997), Humboldt Fellow (Hanover, 2002, 2005),
Alfried Krupp Senior Fellow (Greifswald, Germany, 2007-2008)

Department of Geology & Mining
Faculty of Natural & Applied Sciences
Nasarawa State University,Keffi, Nigeria

13th August 2008

Professor Nuhu OBAJE

Nuhu Obaje is Professor of Geology at the Nasarawa State University, Keffi, Nigeria. He was formerly the Dean of the Faculty of Natural & Applied Sciences and Head of the Department of Geology & Mining (Jan. 2004 – April 2008). He is a member of the Governing Council of the institution. As Dean of the Faculty of Natural & Applied Sciences, he supervised the accreditation of all the courses in the Faculty and was instrumental to several collaborations and university-industry partnerships.

Professor Obaje was selected by the Alfried Krupp Foundation in 2007 as one of five Senior Research Scientists selected on a world-wide competition for scientists who have made significant contributions to scientific research in their specialized fields to spend occasional time at the Alfried Krupp Institute for Advanced Studies in Greifswald, Germany to complete a selected major research work.

Professor Obaje was born on the 15th December 1961 at Ajaka in Igalamela Local Government Area of Kogi State (Nigeria). He attended Barewa College Zaria in the period from 1974 to 1979 and obtained the West African School Certificate (WASC/GCE) in Division One in June 1979. He later graduated B.Sc. (2nd Class Upper Division) and M.Sc. Geology from the Ahmadu Bello University, Zaria in 1984 and 1987 respectively; and the Ph.D. Geology from the University of Tuebingen (Germany) in 1994.

Professor Obaje was later awarded the Royal Society of London postdoctoral fellowship in petroleum geochemistry at the University of Aberdeen, Scotland in 1997; the German Academic Exchange Service (reinvitation) postdoctoral fellowship in biostratigraphy at the University of Tuebingen in 1998; and the Alexander von Humboldt research fellowship in organic geochemistry and organic petrology at the Federal Institute for Geosciences and Natural Resources in Hanover/Germany in 2002-2003. (for one year) and 2005 – 2006 (for 3 months). Professor Obaje also held research tenures in the Exploration Departments of Chevron Nigeria Limited, Lagos (1997-1998) and the Shell Petroleum Development Company of Nigeria Limited in Portharcourt (2000-2001). He has served as a Lecturer at the Ahmadu Bello University, Zaria (1985 – 1997) and was Associate Professor at the Tafawa Balewa University Bauchi up to December 2003. He also served as an Assistant Director and Special Assistant to then Executive Chairman and former Head of Service (Alhaji Adamu Fika) at the Federal Character Commission of the Presidency in Abuja briefly between 1999 and 2000, before leaving for Shell.

Nuhu was a recipient of the American Association of Petroleum Geologists' Grants-in-Aid (maximum cash awardable) for parts of his Ph.D. research on the petroleum geology of the Benue Trough and was two times first prize award winner for the best papers presented at the 28th and 33rd annual conferences of the Nigerian Mining and Geosciences Society (NMGS) in 1993 and 2000 respectively (which respectively entailed a one week visit to Elf Petroleum laboratories in Pau, France). His biography is cited in the 19th edition of Marquis Who's Who in the World of 2002. He was also nominated by the American Biographical Institute as Man of the Year for 2004.

Professor Obaje was a member of the Nigerian government Presidential Committee on Oil and Gas Sector Policy Reform for the National Council on Privatization (2000 – 2007). He has been a resource person on several occasions to the Geological Survey of Nigeria Agency on the review of different segments of the geological map of Nigeria. He is also a member of the Steering Committee and Assessor of the Petroleum Technology Development Fund (PTDF) Annual Research Grants Competition programme and resource person in the Peer Review of the PTDF Professorial Chair Endowment programme. He has served as assessor for professorial appointments in several Nigerian universities including ABU-Zaria, University of Ado-Ekiti, FUT-Minna and University of Jos. He has been a longstanding reviewer for scientific papers in the Journal of Mining & Geology, Global Journal of Geological Sciences, Petroleum Training Journal, African Journal of Microbiology Research, etc; and has himself published over 50 articles in reputable international journals. He has served and still serving as external examiner to many Nigerian universities for undergraduate and postgraduate examinations in the geosciences. Widely traveled and cosmopolitan, Nuhu has visited Algeria, Belgium, Benin

Republic, France, Germany, Italy, Niger Republic, Qatar, Switzerland, The Netherlands, Tunisia, United Kingdom, and the United States of America.

Introduction

The geology of Nigeria is made up of the Basement Complex, the Younger Granites, and the Sedimentary Basins. The Basement Complex, which is Precambrian in age, is made up of the Migmatite-Gneiss Complex, the Schist Belts and the Older Granites. The Younger Granites comprise several Jurassic magmatic ring complexes centered around Jos and other parts of north-central Nigeria. They are structurally and petrologically distinct from the Older Granites. The Sedimentary Basins, containing sediment fill of Cretaceous to Tertiary ages, comprise the Niger Delta, the Anambra Basin, the Lower, Middle and Upper Benue Trough, the Chad Basin, the Sokoto Basin, the Mid-Niger (Bida-Nupe) Basin and the Dahomey Basin.

Abundant mineral deposits occur in all the components of Nigerian geology (Basement, Younger Granites, Sedimentary Basins). Solid mineral deposits of economic significance that include gold, iron ore, cassiterite, collumbite, wolframite, pyrochlore, monazite, marble, coal, limestone, clays, barytes, lead-zinc, etc, occur in the different geologic segments of Nigeria and indeed each of the 36 federating states and the Federal Capital Territory has a fair share of the solid mineral inventory of the nation. Oil and gas on the other hand occur prolificly in the Niger Delta Basin with oportunities to add to the national reserve asset existing in the other sedimentary basins, namely the Anambra Basin, the Benue Trough, the Chad Basin, the Sokoto Basin, the Bida Basin and the Dahomey Basin.

Oil and gas account for 95% of the nation's total revenue earnings which has drifted the country into a mono-cultural economic practice. As at date, the hydrocarbon reserves of the nation stand at 35 billion barrels for oil and 180 trillion standard cubic feet for gas. Current production of oil and gas is entirely from the Niger Delta region. Nigeria is 8th largest producer and 6th largest exporter of petroleum globally.

Despite such a huge mineral resources endowment, it is estimated that about 70% of the nation's population live below the poverty line, defined in this context, as living on less than one dollar per day. Abject poverty, violent clashes, kidnapping, extortion etc characterize the oil producing communities in the Niger Delta region. The existing socio-political bureaucratic arrangement gives the political elites, some cartel managers and probably some terrorism sponsors, the access to manipulate the institutions arising as a result of endemic corruption, all of which aggregate to becloud the efficacy of government policies aimed at tackling the natural "resource curse".

At present, there are no serious signs of departure from the status quo in the unfolding regime of the solid minerals sector. The possibility of achieving a socially sustainable and environmentally friendly exploitation of solid mineral resources in Nigeria by mere passage of legislation is seriously doubtful. Law has not proved to be the magic wand for attaining automatic sustainability in resources utilization in Nigeria in view of apparent conflicting stratum of political and economic interests that have always shaped both the design and implementation of the resource laws as well as actual operations of the extractive sector of the Nigerian economy. However, it needs to be pointed out that while sustainable utilization of mineral resources of the country looks doubtful, it may nevertheless be possible with a combination of well-thought out legislation or modification of the nascent mining law and certain institutional reformations in the entire polity.

The concept of the "resource curse," which emerged in the late 1980s alleged that natural resource abundance leads to a host of negative economic, political, and social outcomes. This theory, which directly opposed the prior conventional wisdom that natural resources were good for development, has now been adopted as the new orthodoxy and is espoused by such bodies as the World Bank and International Monetary Fund (IMF).

Comparative cross-country studies on economic performance have shown that an abundance of natural resources, particularly resources such as minerals and oil, can lead to undesirable economic consequences, such as slow or negative economic growth, inflation, low savings, high unemployment, export earnings instability, corruption, poverty, and low levels of human development. The concentration and "lootability" of resources can influence the type of war which takes place. The resource curse is also connected with political regime types, with many cross-country analyses showing that resource rich countries are less likely to be democratic, especially in the cases of oil and mineral wealth.

External forces can both hinder and facilitate development in resource rich countries, Southeast Asia being a prominent example of success, and it is important to look at geo-strategic and geo-economic environments in assessing how natural resource wealth will affect development given the external context. Both social forces and external factors can be of critical importance in understanding why some resource rich countries are prone to bad developmental outcomes while others are not.

The literature on resource curse tends to be overly deterministic in attributing economic performance, civil wars, and political regime types to resource endowments alone. This ignores the substantial variation among resource rich countries and the factors which enable some resource abundant countries to overcome the resource curse. Some concrete suggestions in the literature include redistribution of resource wealth to citizens and privatization of natural resource sectors.

This presentation brings together the research efforts of the presenter over the past years on the geology and mineral resources endowment of Nigeria while it as well presents options that will enhance optimal exploitation of the mineral resource wealth of the nation for her economic growth and socio-political transformation. In this context, the presentation begins with a detailed overview on the geology of Nigeria, mineral resource occurrences and policy options that can enhance the optimal development of the mineral resources.

PART ONE
GEOLOGY - IGNEOUS AND METAMORPHIC ROCKS

1. The Basement Complex

The Basement Complex is one of the three major litho-petrological components that make up the geology of Nigeria. The Nigerian basement complex forms a part of the Pan-African mobile belt and lies between the West African and Congo Cratons and south of the Tuareg Shield (Black; 1980). It is intruded by the Mesozoic calc-alkaline ring complexes (Younger Granites) of the Jos Plateau and is unconformably overlain by Cretaceous and younger sediments. The Nigerian basement was affected by the 600Ma Pan-African orogeny and it occupies the reactivated region which resulted from plate collision between the passive continental margin of the West African craton and the active Pharusian continental margin (Burke and Dewey, 1972; Dada, 2006). The basement rocks are believed to be the results of at least four major orogenic cycles of deformation, metamorphism and remobilization corresponding to the Liberian (2700 Ma), the Eburnean (2000 Ma), the Kibaran (1100 Ma), and the Pan-African cycles (600 Ma). The first three cycles were characterized by intense deformation and isoclinal folding accompanied by regional metamorphism, which was further followed by extensive migmatization. The Pan-African deformation was accompanied by a regional metamorphism, migmatization and extensive granitization and gneissification which produced syntectonic granites and homogeneous gneisses (Abaa, 1983). Late tectonic emplacement of granites and granodiorites and associated contact metamorphism accompanied the end stages of this last deformation. The end of the orogeny was marked by faulting and fracturing (Gandu et al., 1986; Olayinka, 1992)

Within the basement complex of Nigeria four major petro-lithological units are distinguishable, namely:

1. The Migmatite – Gneiss Complex (MGC)
2. The Schist Belt (Metasedimentary and Metavolcanic rocks)
3. The Older Granites (Pan African granitoids)
4. Undeformed Acid and Basic Dykes

The Migmatite – Gneiss Complex (MGC)

The Migmatite – Gneiss Complex is generally considered as the basement complex sensu stricto (Rahaman, 1988; Dada, 2006) and it is the most widespread of the component units in the Nigerian basement. It has a heterogeneous assemblage comprising migmatites, orthogneises, paragneisses, and a series of basic and ultrabasic metamorphosed rocks. Petrographic evidence indicates that the Pan- African reworking led to recrystallization of many of the constituent minerals of the Migmatite – Gneiss Complex by partial melting with majority of the rock types displaying medium to upper amphibolite facies metamorphism. The Migmatite – Gneiss Complex has ages ranging from Pan-African to Eburnean.

The Migmatitie-Gneiss Complex also termed by some workers as the "migmatite-gneiss-quartzite complex" makes up about 60% of the surface area of the Nigerian basement (Rahaman and Ocan, 1978). These rocks record three major geological events (Rahaman and Lancelot, 1984); the earliest, at 2,500 Ma, involved initiation of crust forming proceses (e.g. the banded Ibadan grey gneiss of mantle origin) and of crustal growth by sedimentation and orogeny; next came the Eburnean, 2000 $\pm$ 200 Ma, marked by the Ibadan type granite gneisses; this was followed by ages in the range from 900 - 450 Ma which represent the imprint of the Pan-African event which not only structurally overprinted and re-set many geochronological clocks in the older rocks, but also gave rise to granite gneisses, migmatites and other similar lithological units. The close analogy in time with the development of the Birrimian of the West African Craton is striking. However, although gold, manganese and iron mineral deposits are associated with Birrimian rocks, the same age rocks in Nigeria are very sparsely, if at all, mineralized. The extent of Eburnean and older rocks in Nigeria is not known. Definite geochemical evidence for the existence of these rocks exists for the area south of latitude 9°N (Rahaman and Lancelot, 1983). Lithologically similar rocks in other parts of Nigeria, especially in the northeast and southeast, have given only Pan-African ages (Tubosun, 1983).

Many areas in northern, western and eastern Nigeria are covered by rocks of the Migmatite – Gneiss Complex. These areas include, but not limited to: Abuja, Keffi, Akwanga, Bauchi, Kaduna, Kano, Funtua, Okenne, Egbe, Ajaokuta (in northern Nigeria); Ibadan, Ile-Ife, Akure, Ikerre, (in western Nigeria) and Obudu and the Oban Massif areas in eastern Nigeria.

The Schist Belt (Metasedimentary and Metavolcanic Rocks)

The Schist Belts comprise low grade, metasediment-dominated belts trending N-S which are best developed in the western half of Nigeria. These belts are considered to be Upper Proterozoic supracrustal rocks which have been infolded into the migmatite-gneiss-quartzite complex. The lithological variations of the schist belts include coarse to fine grained clastics, pelitic schists, phyllites, banded iron formation, carbonate rocks (marbles / dolomitic marbles) and mafic metavolcanics (amphibolites). Some may include fragments of ocean floor material from small back-arc basins. Rahaman (1976) and Grant (1978) for example suggest that there were several basins of deposition whereas Oyawoye (1972) and McCurry (1976) consider the schists belts as relicts of a single supracrustal cover. Olade and Elueze (1979) consider the schist belts to be fault-controlled rift-like structures. Grant (1978), Holt (1982) and Turner (1983), based on structural and lithological associations, suggest that there are different ages of sediments. However, Ajibade et al. (1979) disagree with this conclusion and show that both series contained identical deformational histories. The structural relationships between the schist belts and the basement were considered by Truswell and Cope (1963) to be conformable metamorphic fronts and it was Ajibade et al. (1979) who first mapped a structural break. ve cross-cutting Older Granites provide a lower limit of ca 750 Ma. A Rb/Sr age of 1040 ± 25 Ma for the Maru Belt phyllites has been accepted as the metamorphic age by Ogezi (1977).

The schist belt rocks are generally considered to be Upper Proterozoic. The geochemistry of the amphibolite complexes within the schist belts has also led to some controversies. Klemm et al. (1984) have concluded that the Ilesha Belt may be an Archaean greenstone belt. Olade and Elueze (1979), Ogezi (1977) and Ajibade (1980) have favoured dominantly ensialic processes in the evolution of the schist belts while Ajayi (1980), Rahaman (1981) and Egbuniwe (1982) have stressed that some include oceanic materials with tholeiitic affinities. Some metallogenetic features of the schist belts are relevant to these problems; the apparent absence of subduction related mineral deposits may be indicative of a limited role for the ensimatic processes; the distribution of primary gold occurrences in some belts but its marked absence in others may indicate that they do not represent a single supracrustal sequence. The schist belts are best developed in the western part of Nigeria, west of 8°E longitude, though smaller occurrences are found to the east but only sporadically. The belts are confined to a NNE-trending zone of about 300 km wide. The area to the west of this zone is made up of gneisses and migmatites that constitute the Dahomeyan of Burke and Dewey (1972). Similarly, to the east, no schist belts are known for a distance of 700 km until in Cameroun where a number of schist belts, considered to be Upper Proterozoic, occur in the Pan-African granite-migmatite terrain north of the Congo Craton.

The schist belts have been mapped and studied in detail in the following localities: Maru, Anka, Zuru, Kazaure, Kusheriki, Zungeru, Kushaka, Isheyin Oyan, Iwo, and Ilesha where they are known to be generally associated with gold mineralization.

The Older Granites (Pan African Granitoids)

The term 'Older Granite' was introduced by Falconer (1911) to distinguish the deep-seated, often concordant or semi-concordant granites of the Basement Complex from the high-level, highly discordant tin-bearing granites of Northern Nigeria. The Older Granites are believed to be pre-, syn- and post-tectonic rocks which cut both the migmatite-gneiss-quartzite complex and the schist belts. They range widely in age (750-450 Ma) and composition. They represent a varied and long lasting (750-450 Ma) magmatic cycle associated with the Pan-African orogeny. The rocks of this suite range in composition from tonalites and diorites through granodiorites to true granites and syenites. Charnockites form an important rock group emplaced during this period. They are generally high level intrusions and anataxis has played an important role (Rahaman, 1981). The Older Granites suite is notable for its general lack of associated mineralization although the thermal effects may play a role in the remobilization of mineralizing fluids.

The Older Granites are the most obvious manifestation of the Pan-African orogeny and represent significant additions of materials (up to 70% in some places) to the crust (Rahaman, 1988). Attempt to classify the Older Granites with respect to timing during an orogenic event are valid over only short distances. Contact features between members of the Older Granites suite suggest the coexistence of several magmas. Compositionally, the granites plot in the field of calc-alkaline rocks on the AFM diagram and although they contain significant amount of alkalis, are also often slightly corundum normative. Dada (2006) was of the opinion that the term “Pan African Granitoids” be used for the Older Granites not only on the merit of age which was not available at the time they were named Older Granites, but because it covers several important petrologic groups formed at the same time.

The granitoids which outcrop with the schist belts in northwestern and southwestern Nigeria include biotite granites, biotite muscovite granites, syenites, charnockites, serpentinites and anorthosites.

In northern Nigeria, the abundance of Pan-African granites appears to increase eastward. In the area west of Zaria these occur as isolated intrusions (McCurry, 1973), whereas in the region between Rahama and the Mesozoic-Cenozoic cover, the intrusive granites and related rocks envelope remnants of migmatites. McCurry (1973) working mainly west of Zaria divided the granites into two main groups according to their field relationships. The first "syntectonic" group comprised elongate batholithic sheets that are partly concordant, and foliated. The second group "late tectonic" are made up of poorly foliated discordant bodies, rich in mafic xenoliths and having a lower proportion of potash feldspar. The late granites are considered to be the products of widespread mobilisation and reactivation of older basement rocks during the Pan-African orogeny. The Older Granites occur intricately associated with the Migmatite-Gneiss Complex and the Schist Belts into which they generally intruded. Older Granite rocks therefore occur in most places where rocks of the Migmatite-Gneiss Complex or of the Schist Belt occur. However, Older Granites are particularly noteworthy in and around Wusasa (Zaria), Abuja, Bauchi, Akwanga, Ado-Ekiti and Obudu areas. In Bauchi area and some parts of southwestern Nigeria, most of the Older Granite rocks occur as dark, greenish-grey granites with significant quantities of olivine (fayalite) and pyroxene occurring with quartz, feldspars and micas. For this unusual composition, the Older Granites in these areas are termed Bauchite (in Bauchi area) and Oyawoyite (After Professor Oyawoye who first mapped them) in southwestern Nigeria. For uniformity of terminology, both the Bauchites and Oyawoyites constitute the charnockitic rocks (Charnockites) of the Basement Complex.

Undeformed Acid and Basic Dykes

The undeformed acid and basic dykes are late to post-tectonic Pan African. They cross-cut the Migmatite-Gneiss Complex, the Schist Belts and the Older Granites. The undeformed acid and basic dykes include:

a. Felsic dykes that are associated with Pan African granitoids on the terrain such as the muscovite, tourmaline and beryl bearing pegmatites, microgranites, aplites and syenite dykes (Dada, 2006)
b. Basic dykes that are generally regarded as the youngest units in the Nigerian basement such as dolerite and the less common basaltic, felsite and lamprophyric dykes.

The age of the felsite dykes has been put at between 580 and 535 Ma from Rb-Sr studies on whole rocks (Mathies and Caen-Vachette, 1983; Dada, 2006), while the basic dykes have a much lower suggested age of ca. 500 Ma (Grant, 1970). The structural and geochronological importances of this suite of rocks, which have been put to immense chronological use elsewhere (Dada, 2006) are often overlooked in Nigeria. When they cross-cut basement, they could be used to infer relative age of metamorphic structures and rock suites and could also suggest the existence of older basement windows in the Nigerian schist belts, apart from the immense guide they provide in sampling for isotope geochemistry, analysis and interpretation (Dada, 2006).

2. The Younger Granites

General Description

The Mesozoic Younger Granite ring complexes of Nigeria form part of a wider province of alkaline anorogenic magmatism. They occur in a zone 200 km wide and 1600 km long extending from northern Niger to south central Nigeria. Rb/Sr whole rock dating indicates that the oldest complex of Adrar Bous in the north of Niger is Ordovician in age, with progressively younger ages southwards. The most southerly ring complex of Afu is Late Jurassic in age (Bowden et al., 1976). Aeromagnetic anomalies suggest that a series of buried NE-SW lineaments of incipient rifts controlled the disposition of the individual complexes (Ajakaiye, 1983).

More than 50 complexes occur in Nigeria varying from <2 to >25 km in diameter (Kinnaird, 1981). The ring complexes cover a total area of about 7500 km^2 with individual massifs varying from 1000 km^2 to <1 km^2. The majority are between 100 and 250 km^2 with circular or elliptical outlines. Each of the ring complexes, whether they consist of overlapping centres, as at Ningi-Burra, or individual centres, such as Ririwai, began as chains of volcanoes (Bowden and Kinnaird, 1984). Early ash-fall tufts and agglomerates were deposited from eruptions of explosive activity. Abundant ignimbrites deposited from ash flows dominate thc volcanics with only minor rhyolitic and thin basic flows. Volcanic feeder intrusions are a minor but important link during the caldera-forming stage, between the subvolcanic roots and the overlying volcanic pile. Fayalite hedenbergite quartz porphyry often has ignimbritic textures.

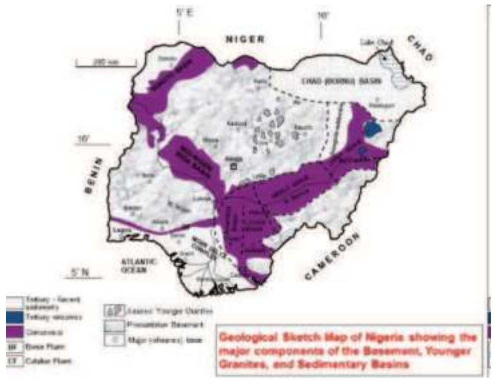
The Younger Granites are discordant high level intrusions emplaced by means of piecemeal stoping through the collapsed central block. Erosion of the volcanics in the more southerly complexes has revealed good exposures of granite. The granitoid suite is more than 95% granite. Intermediate and basic rocks constitute less than 5% of the area. There are several distinctive granite types:

(i) Peralkaline granites and related syenites (with alkali or calcic amphibole in the compositional range ferrorichterite to arfvedsonite in the granites and ferrodenite to ferroactinolite in the syenites) plot close to Q-A join in the Streckeisen Q-A-P plot;

(ii) Peraluminous biotite alkali feldspar granites and biotite syenogranites plot close to the boundary between the two fields on the Streckeisen diagram.

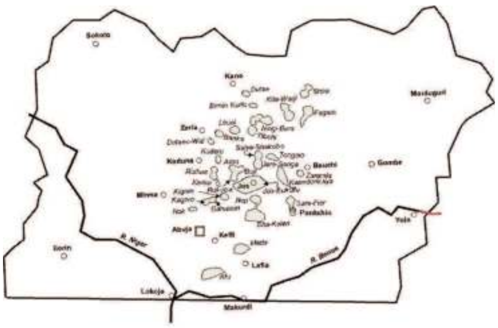
(iii) Metaluminous fayalite and hornblende-bearing granites and porphyries with amphiboles or biotite plot in the granite field.

The granites of the Younger Granites series are mainly in the form of ring complexes, of soda pyroxenes and amphiboles, biotite, and fayalite granites, syenites and trachytes with minor gabbros and dolerites. Rhyolites, tufts and ignimbrites are rarely preserved. The centres normally overlap one another, and there is a general tendency for a southern shift in intrusion. However, NE trending alignments of complexes are noticeable, perhaps reflecting deep seated zones of weakness in the basement, but there are no obvious surface relationships between location and regional tectonic features (Black and Girod, 1970). The complexes have been well studied, partly because of their classical structures, petrographic type, and mid-plate anorogenic character, but not least for their economic interest since they are associated with considerable cassiterite, wolframite, scheelite and zinc mineralization, and have sustained an important alluvial tin mining industry. Fifteen of the complexes have been isotopically dated and a perceptable trend in the north from 213 $\pm$ 7 Ma (Dutse), 186 $\pm$ 15 Ma (Zaranda) and 183 $\pm$ 7 Ma (Ningi-Burra) to those in the south at 151 $\pm$ 4 Ma (Pankshin), 145 $\pm$ 4 Ma (Mada), and 141 $\pm$ 2 Ma (Afu) is discernable. This progressive change in age, and the fact that similar alkali granite ring complexes in southern Niger and further north in Air are Carboniferous, Devonian and Ordovician in age has prompted authors (e.g. Bowden et al.,. 1976) to advocate a sequential age trend covering some 500 Ma over a distance of more than 2000 km. More recently Rahaman et al. (1984) and Bowden and Karche (1984) have provided further isotopic evidence of this age progression. Of all the African ring complex provinces the Younger Granites of Nigeria have been most studied, and although providing fine examples of ring structures and petrogenetic evolution, these features can be as well seen in other provinces. They are however, economically more significant (Kinnaird, 1984) than any of the other groups, excluding the carbonatite complex of Palabora (Bowden and Kinnaird, 1984). Major characteristics of the Nigerian Younger Granite rocks in comparism to the Older Granite suites are given in the Explanatory Note below.

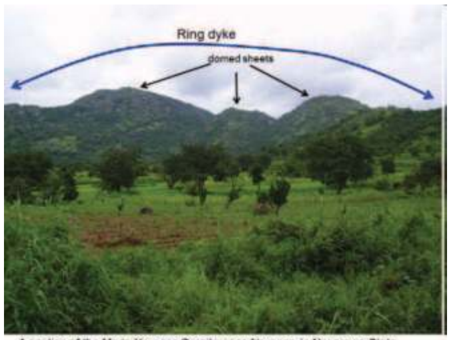


Geological Sketch Map of Nigeria showing the major components of the Basement, Younger Granites, and Sedimentary Basins

Schist Belt Localities in Nigeria within the context of the regional geology of parts of West Africa (After Wright, 1985)



Major Younger Granites Localities in Nigeria



A section of the Mada Younger Granite near Akwanga in Nasarawa State. Note the migrating domed sheets and the ring nature


A portion of the Kagoro Younger Granite visible on the Forest – Jos road. Domed sheets are less developed, but the dyke is extensive

Jos – Bukuru Younger Granite from afar (viewed from Tilden Fulani). Note outer ring and inner ring

PART TWO
GEOLOGY - SEDIMENTARY BASINS

3. The Benue Trough

The Benue Trough of Nigeria is a rift basin in central West Africa that extends NNE-SSW for about 800 km in length and 150 km in width. The southern limit is the northern boundary of the Niger Delta, while the northern limit is the southern boundary of the Chad Basin. The trough contains up to 6000m of

Cretaceous - Tertiary sediments of which those predating the mid-Santonian have been compressionally folded, faulted, and uplifted in several places. Compressional folding during the mid-Santonian tectonic episode affected the whole of the Benue Trough and was quite intense, producing over 100 anticlines and synclines (Benkhelil, 1989). Major such deformational structures include the Abakaliki anticlinorium and the Afikpo syncline in the Lower Benue, the Giza anticline and the Obi syncline in the Middle Benue, and the Lamurde anticline and the Dadiya syncline in the Upper Benue Trough.

Following mid-Santonian tectonism and magmatism, depositional axis in the Benue Trough was displaced westward resulting in subsidence of the Anambra Basin. The Anambra Basin, therefore, is a part of the Lower Benue Trough containing post-deformational sediments of Campanian-Maastrichtian to Eocene ages. It is logical to include the Anambra Basin in the Benue Trough, being a related structure that developed after the compressional stage (Akande and Erdtmann, 1998).

The Benue Trough is arbitrarily subdivided into a lower, middle and upper portion. No concrete line of subdivision can be drawn to demarcate the individual portions, but major localities (towns/settlements) that constitute the depocentres of the different portions have been well documented (Petters, 1982; Nwajide, 1990; Idowu and Ekweozor, 1993; Obaje et al., 1999). The depocentres of the Lower Benue Trough comprise mainly the areas around Nkalagu and Abakaliki, while those of the Anambra Basin centre around Enugu, Awka and Okigwe. The Middle Benue Trough comprises the areas from Makurdi through Yandev, Lafia, Obi, Jangwa to Wukari. In the Upper Benue Trough, the depocenters comprise Pindiga, Gombe, Nafada, Ashaka (in the Gongola Arm) and Bambam, Tula, Jessu, Lakun, and Numan in the Yola Arm.

The Lower Benue Trough and the Anambra Basin

Sedimentation in the Lower Benue Trough commenced with the marine Albian Asu River Group, although some pyroclastics of Aptian – Early Albian ages have been sparingly reported (Ojoh, 1992). The Asu River Group in the Lower Benue Trough comprises the shales, limestones and sandstone lenses of the Abakaliki Formation in the Abakaliki area and the Mfamosing Limestone in the Calabar Flank (Petters, 1982). The marine Cenomanian - Turonian Nkalagu Formation (black shales, limestones and siltsones) and the interfingering regressive sandstones of the Agala and Agbani Formations rest on the Asu River Group. Mid-Santonian deformation in the Benue Trough displaced the major depositional axis westward which led to the formation of the Anambra Basin. Post-deformational sedimentation in the Lower Benue Trough, therefore, constitutes the Anambra Basin. Sedimentation in the Anambra Basin thus commenced with the Campanian-Maastrichtian marine and paralic shales of the Enugu and Nkporo Formations, overlain by the coal measures of the Mamu Formation. The fluviodeltaic sandstones of the Ajali and Owelli Formations lie on the Mamu Formation and constitute its lateral equivalents in most places. In the Paleocene, the marine shales of the Imo and Nsukka Formations were deposited, overlain by the tidal Nanka Sandstone of Eocene age. Downdip, towards the Niger Delta, the Akata Shale and the Agbada Formation constitute the Paleogene equivalents of the Anambra Basin.

The Enugu and the Nkporo Shales represent the brackish marsh and fossiliferous pro–delta facies of the Late Campanian–Early Maastrichtian depositional cycle (Reijers and Nwajide, 1998). Deposition of the sediments of the Nkporo/Enugu Formations reflects a funnel-shaped shallow marine setting that graded into channeled low-energy marshes. The coal-bearing Mamu Formation and the Ajali Sandstone accumulated during this epoch of overall regression of the Nkporo cycle. The Mamu Formation occurs as a narrow strip trending north-south from the Calabar Flank, swinging west around the Ankpa plateau and terminating at Idah near the River Niger. The Ajali Sandstone marks the height of the regression at a time when the coastline was still concave. The converging littoral drift cells governed the sedimentation and are reflected in the tidal sand waves which are characteristic for the Ajali Sandstone. The best exposure of the Nkporo Shale is at the village of Leru (Lopauku), 72 km south of Enugu on the Enugu – Portharcourt express road, while that of Enugu Shale is at Enugu, near the Onitsha-Road Flyover. The Mamu Formation is best exposed at the Miliken Hills in Enugu, with well-preserved secions along the road cuts from the King Petrol Station up the Miliken Hills and at the left bank of River Ekulu near the bridge to Onyeama mine.

The Nsukka Formation and the Imo Shale mark the onset of another transgression in the Anambra Basin during the Paleocene. The shales contain significant amount of organic matter and may be a potential source for the hydrocarbons in the northern part of the Niger Delta (Reijers and Nwajide, 1998). In the Anambra Basin, they are only locally expected to reach maturity levels for hydrocarbon expulsion. The Eocene Nanka Sands mark the return to regressive conditions. The Nanka Formation offers an excellent opportunity to study tidal deposits. Well-exposed, strongly assymetrical sandwaves suggest the predominance of flood-tidal currents over weak ebb-reverse currents. The presence of the latter are only suggested by the bundling of lamine separated from each other by mud drapes reflecting neap tides. A good outcrop of the Nanka Formation is the Umunya section, 18 km from the Niger Bridge at Onitsha on the Enugu - Onitsha Expressway.

The Middle Benue Trough

In the Middle Benue Trough, around the Obi/Lafia area, six Upper Cretaceous lithogenic formations comprise the stratigraphic succession. This succession is made up of Albian Arufu, Uomba and Gboko Formations, generally referred to as the Asu River Group (Offodile, 1976; Nwajide, 1990). These are overlain by the Cenomanian – Turonian Keana and Awe Formations and the Cenomanian – Turonian Ezeaku Formation. The Ezeaku Formation is coterminous with the Konshisha River Group and the Wadata Limestone in the Makurdi area. The Late Turonian – Early Santonian coal-bearing Awgu Formation lies conformably on the Ezeaku Formation. In the Makurdi area, the Makurdi Sandstone interfingers with the Awgu Formation. The mid-Santonian was a period of folding throughout the Benue Trough. The post-folding Campano-Maastrichtian Lafia Formation ended the sedimentation in the Middle Benue Trough, after which widespread volcanic activities took over in the Tertiary.

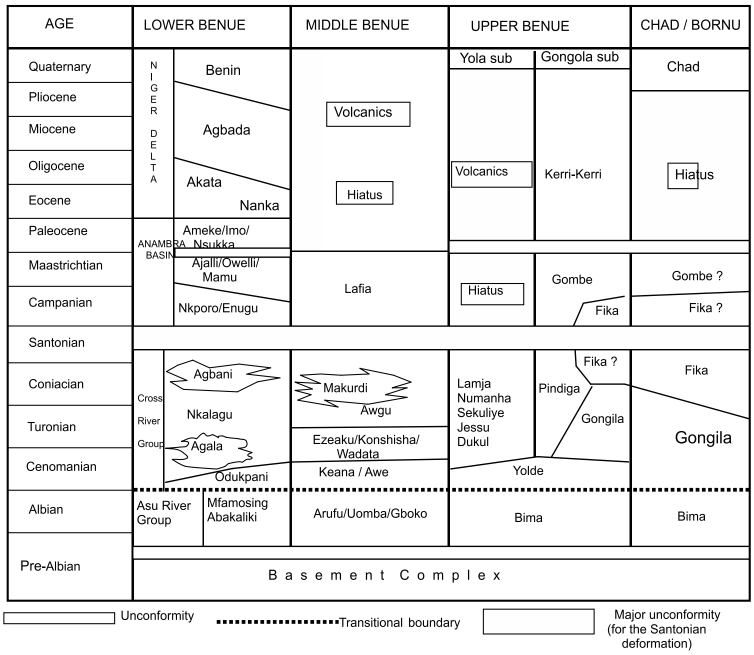
The Asu River Group outcrops mainly in the Keana anticline east of Keana town and south of Azara; and in the area around Gboko with a typical section in the Quarry of the Benue Cement Company near Yandev. The lithologic composition of the Asu River Group comprises limestones, shales, micacous siltstones, mudstones and clays (Offodile, 1976; Obaje, 1994). The average thickness is estimated to be about 1,800m.

The Awe Formation was deposited as passage (transitional) beds during the Late Albian Early Cenomanism regression. Its typical sections occur around the town of Awe, where Offodile (1976) estimated the thickness to be about 100m. The formation consists of flagy, whitish, medium to coarse grained calcareous sandstones, carbonaceous shales and clays. The Keana Formation resulted from the Cenomanian regression which deposited fluviodeltaic sediments. The formation consists of cross-bedded, coarse grained feldsparthic sandstones, occasional conglomerates, and bands of shales and limestones towards the top. Massive outcrops occur at Keana, Noku, Chikinye, Jangerigeri, Azara, and Daudo.

The deposition of the Ezeaku Formation is attributed to the beginning of marine transgression in the Late Cenomanian. The sediments are made up mainly of calcareous shales, micaceous fine to medium friable sandstones and beds of limestones which are in places shelly. The deposition took place in a presumably shallow marine coastal environment. Outcrops of the Ezeaku Formation include those at Ortesh, about 4 km east of the village of Jangerigeri, where the sediments are composed mainly of shelly limestones (almost entirely of oystr shell). In the bank of River Tokura, about 20 km east of Keana town, on the Chikinye – Awe road, a typical section of the Ezeaku Formation occurs, consisting mainly of intercalations of shelly limestones and black shales, with brownish fine to coarse grained feldspartic sandstones at the top.

The deposition of the Awgu Formation marks the end of marine sedimentation in this part of the Benue Trough. The formation is made up of bluish-grey to dark-black carbonaceous shales, calcareous shales, shaley limestones, limestones, sandstones, siltones, and coal seams. The major outcrop of the coal-bearing Awgu Formation is at the bank of River Dep in Shankodi, 7km to the west of the village of Jangwa. Along the bank of this river, the coal seams can be traced laterally for about 500 m. The borehole cores of the Steel Raw Materials Exploration Agency (formerly National Steel Council) stock-piled at the Obi camp contain coal seams and coal bands at various depths within the Awgu Formation. The occurrence of low diversity arenaceous foraminifera in the Awgu Formation indicate deposition in marshy, deltaic and shallow marine conditions (Obaje, 1994)

The Lafia Formation is the youngest formation in this area. The formation was deposited under continental condition (fluviatile) in the Maastrichtian and lies unconformably on the Awgu Formation. It is lithologically characterized by ferruginized sandstones, red, loose sands, flaggy mudstones, clays and claystones. Outcrops and sections of the Lafia Formation occur in and around the town of Lafia, and along the bank of River Amba on the Lafia – Doma road.



Stratigraphic successions in the Benue Trough and the Nigerian sector of the Chad Basin

The Upper Benue Trough

The Upper Benue Trough is made up of two arms, the Gongola Arm and the Yola Arm (although some authors have sub-divided the Upper Benue Trough to include a third central Lau-Gombe sub-basin, eg. Akande et al., 1998). In both arms of the basin, the Albian Bima Sandstone lies unconformably on the Precambian Basement. This formation was deposited under continental conditions (fluvial, deltaic, lacustrine) and is made up of coarse to medium grained sandstones, intercalated with carbonaceous clays, shales, and mudstones. The Bima Sandstone was subdivided by Carter et al. (1963) into a Lower, Middle and Upper Bima. The Middle Bima is reported to be shaley in most parts with some limestone intercalations and was assumed to be deposited under a more aqueous anoxic condition (lacustrine, brief marine). An approximation to this description are the dark, carbonaceous shales within the Bima Sandstone in the section along the river channel to the south of the bridge, 200 mm (just) before the village of Bambam. Similar shales also occur within units of the Bima Sandstone that outcrop extensively on the Lamurde anticline (2 km to the town of Lafiya, on the Gombe – Numan road). Good exposures of the Bima Sandstone (however, without the so-called Middle Bima can be studied at Biliri, Filiya and Shani.

The Yolde Formation lies conformably on the Bima Sandstone. This formation of Cenomanian age represents the beginning of marine incursion into this part of the Benue Trough. The Yolde Formation was deposited under a transitional/coastal marine environment and is made up of sandstones, limestones, shales, clays and claystones. Typical localities of the Yolde Formation are along the valley of Pantami River in Gombe town and in the village of Yolde, 50 km to Numan town.

In the Gongola Arm, the laterally equivalents Gongila and Pindiga Formations and the possibly younger Fika Shale lie conformably on the Yolde Formation. These formations represent full marine incursion into the Upper Benue during the Turonian – Santonian times. Lithologically, these formations are characterized by the dark/black carbonaceous shales and limestones, intercalating with pale colored limestones, shales and minor sandstones. The type locality of the Gongila Formation is at the Quarry of the Ashaka Cement Company at Ashaka, while that of Pindiga Formation is at Pindiga village. The Fika Shale is lithologically made up of bluish-greenish carbonaceous, sometime pale gypsiferous, highly fissile shales and occasional limestones in places. The formation is entirely marine and has its type locality at Nafada village on the Gombe – Ashaka road.

In the Yola Arm, the Dukul, Jessu and Sekuliye Formations, the Numanha Shale, and the Lamja Sandstone are the Turonian – Santonian equivalents of the Gongila and Pindiga Formations. The Turonian - Santonian deposits in the Yola Arm are lithologically and palaeo environmentally similar to those in the Gongola Arm, except the Lamja Sandstone which has a dominating marine sandstone lithology. The recovery of diversed assemblages of arenaceous alongside planktonic foraminifera from samples obtained from the Dukul, Jessu and Sekuliye formations (Fig. 15a, b) indicate deposition in shallow marine – neritic - shelfal environments. The type locality of the Dukul Formation is in the village of Dukul with good exposures also at Bambam and Lakun on the Gombe – Yola road. All the other formations have their type localities in the villages named after them.

The Santonian was a period of folding and deformation in the whole of the Benue Trough. Post-folding sediments are represented by the continental Gombe Sandstone of Maastrichtian age and the Keri-Keri Formation of Tertiary age. The Gombe Sandstone is lithologically similar to the Bima Sandstone, attesting to the re-establishment of the Albian palaeoenvironmental condition. The Gombe Sandstone Formation, however, contains coal, lignite, and coally shale intercalations which in places are very thick. The type locality of the Gombe Sandstone is along the bank of Pantami River in town. Good exposures are also encountered in many parts of Gombe town and Birin Fulani village.

The Kerri-Kerri Formation is made up of whitish grey sandstones, siltstones, and claystones with the claystones dominating the lithology in most places, Typical sections are exposed in Gombe Aba, Duku (not Dukul) and Alkaleri.

4. The Bornu Basin
(Nigerian Sector of the Chad Basin)

The Nigerian sector of the Chad Basin, known locally as the Bornu Basin, is one of Nigeria's inland basins occupying the northeastern part of the country. It represents about one-tenth of the total area extent of the Chad Basin, which is a regionally, large structural depression common to five countries, namely, Cameroon, Central African Republic, Niger, Chad, and Nigeria. The Bornu Basin falls between latitudes 11^0N and 14^0N and longitudes 9^0E and 14^0E, covering Borno State and parts of Yobe and Jigawa States of Nigeria.

The Chad Basin belongs to the African Phanerozoic sedimentary basins whose origin is related to the dynamic process of plate divergence. Notable exceptions, however, are the deformed basinal sequences of the Paleozoic fold belts of Moroco and Mauritania which resulted from the Hercynian convergent motion and collision of Africa and North America, and the Tindouf and Ougarta basins which are Paleozoic successor basins (Burke, 1976; Petters, 1982). It is an intracratonic inland basin covering a total area of about 2,335,000 km^2 with Niger and Chad Republics sharing more than half of the basin. The basin belongs to a series of Cretaceous and later rift basins in Central and West Africa whose origin is related to the opening of the South Atlantic (Obaje et al., 2004).

Lithostratigraphy

Geologic outcrops in the Chad Basin are scarce, being blanketed by Quaternary sediments. The rare exposures of the older series of Early Cretaceous are mostly found in the Niger Republic part of the basin. The sedimentary fill in most parts of the basin is made of Late Cenozoic – middle Eocene continental sediments and Cretaceous and Tertiary series accumulating preferentially in tectonic rifts. Data gathered from the adjacent basins and boreholes indicate that the Bornu Basin is made up of five stratigraphic units that include the Bima Sandstone at the bottom, the Gongila Formation, the Fika Shale, the Kerri – Kerri and Chad Formations. In most cases the Chad Formation lies directly unconformably on the Fika Shale.

The Bima Sandstone

The stratigraphic succession in the Bornu Basin commenced in the Albian – Turonian time with deposition of the Bima Sandstone resting unconformably on the Precambrian basement. This formation is diachronous and probably of Albian – Turonian age. It is a poorly sorted, medium to coarse-grained, thick to massive – bedded, and cross – stratified feldspathic sandstone with variable colors; from brown, reddish brown, grey to white. The Bima Sandstone evolved from the weathering of the basement rocks. It constitutes the upper part of the regionally known Continental Intercalaire. This comprises all sediments derived from the Basement Complex between the Permian and Albian times in response to uplift and weathering..

The Gongila Formation

The Bima Sandstone is overlain by the Gongila Formation This is composed of thin to moderately thick interbeds of calcareous gray to dark shales and silty sandstones deposited in a shallow-marine environment. The deposition of this formation is taken to mark the onset of marine incursion into the Chad Basin in the Turonian (Olugbemiro et al., 1997; Obaje et al., 2004). Carter et al. (1963) recorded an average thickness of 420m and the occurrence of numerous Cenomanian – lower Turonian ammonites from the basal limestone facies in outcrop of the formation in adjacent basin. Avbovbo et al. (1986) reported a thickness of 0 – 800m from seismic data while Okosun (1995) and

Olugbemiro et al. (1997) recorded a thickness of 1410m from Kinasar-1 well and between 162 – 420m from Kanadi and Albarka wells respectively.

The Fika Shale

The Fika (Shale) Formation overlies the Gongila Formation and was deposited during the continued marine transgression in the Turonian–Coniacian. Carter et al. (1963) dated this formation as Turonian – Maastrichtian in age. It is a fully marine blue - black shale locally gypsiferous with intercalation of limestones. The recovery of diversed assemblages of arenaceous alongside planktonic foraminifera (Fig. 16a, b) in samples obtained from the Fika Shale indicates deposition in shallow to deep marine environments. Thicknesses of 430m, 0-900m, 890m and 840-1453m were recorded from exploratory wells by Carter et al. (1963), Avbovbo et al. (1986), Okosun (1995) and Olugbemiro et al. (1997), respectively. The Fika Shale and the underlying Gongila Formation are said to constitute the potential petroleum source rocks in the Bornu Basin (Moumouni et al., 2006).

The Gombe Sandstone

This formation has not been penetrated by wells used variously in the past for the study of the Chad Basin and its occurrence in any significant proportion in the basin is doubtful. Generally, it is made of intercalations of siltstones, shales and ironstones but without coal seam interactions as in the Upper Benue Trough (Obaje et al., 1999). The Gombe Sandstone was deposited during the Maastrichtian in an estuarine/deltaic environment.

The Kerri – Kerri Formation

This formation was not encountered in any of the exploratory oil wells drilled by the Nigerian National Petroleum Cooperation (NNPC) since drilling was concentrated north of Maiduguri around Lake Chad. It occurs in the south of the basin along the boundary with the Benue Trough. The formation consists of cross–bedded ferruginized sandstone and massive gritty clay with colors varying from reddish brown, pink, yellow, purple to grey. Carter et al. (1963) measured a thickness of 130m in the adjoining Upper Benue Trough.

The Chad Formation

This is the uppermost Pliocene — Pleistocene formation consisting of fluviatile and lacustrine thick bodies of clay, separating three major sand bodies, with lenses of diatomite up to a few meters thick (Wright., 1985). The sand is uncemented with angular and subangular quartz grains. The clay is massive and locally gritty in texture. Both the sand and the clay are of variable colors ranging from brown, yellow, and white to grey. The three sand bodies correspond to the upper, middle and lower aquifers defined by Barber and Jones (1965). The lower member is made of sands and sandy clays while the middle and the upper consist of sandy clays with diatomite and clays and sands, respectively. Based on exploratory wells studied by Moumouni et al. (2007), the Fika / Chad Formations boundary is fixed at about 1500 meters depth except in Kasade – 1 where it is estimated to be at about 700 meters.

5. The Sokoto Basin
(Nigerian Sector of the Iullemmeden Basin)

The Iullemmeden Basin in north-western Nigeria is known locally as the "Sokoto Basin". It consists predominantly of a gently undulating plain with an average elevation varying from 250 to 400 metres above sea-level. This plain is occasionally interrupted by low mesas. A low escarpment, known as the "Dange Scarp" is the most prominent feature in the basin and it is closely related to the geology.

The sediments of the Iullemmeden Basin were accumulated during four main phases of deposition. Overlying the Pre-Cambrian Basement unconformably, the Illo and Gundumi Formations, made up of grits and clays, constitute the Pre-Maastrichtian "Continental Intercalaire" of West Africa. They are overlain unconformably by the Maastrichtian Rima Group, consisting of mudstones and friable sandstones (Taloka and Wurno Formations), separated by the fossiliferous, shelly Dukamaje Formation. The Dange and Gamba Formations (mainly shales) separated by the calcareous Kalambaina Formation constitute the Paleocene Sokoto Group. The overlying continental Gwandu Formation forms the Post-Paleocene Continental Terminal. These sediments dip gently and thicken gradually towards the northwest, with a maximum thickness of over 1200 m near the frontier with Niger Republic. The geological map of the Sokoto Basin of northwestern Nigeria is shown on Figure 17 while Figure 18 summarizes the geological sequence in the basin.

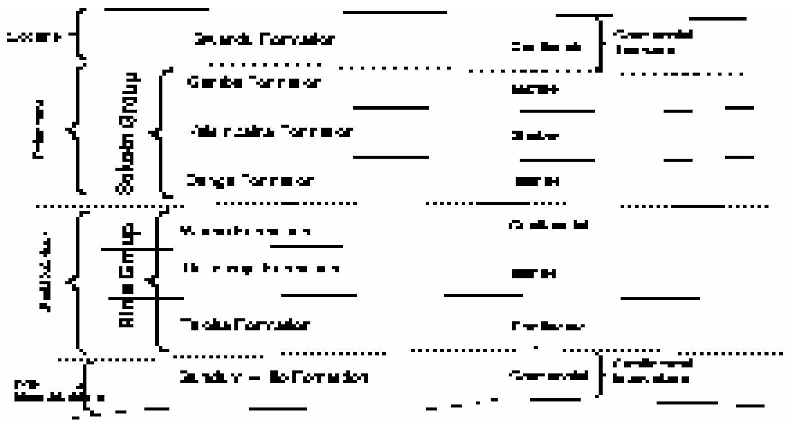
Palaeobiogeographical Deductions and the Transaharan Seaway

Outcrops of the Maastrichtian-Paleocene marine sediments in the Nigerian sector of the Iullemmeden Basin form an arcuate belt that trends in a north-south-west direction. Regionally, the outcrop belt narrows south-westwards where there is pronounced thinning and wedging-out of marine units. They represent the proximal portion of the sedimentary sequence that thickens towards the north-west and attains its maximum development in Niger. Marginal marine conditions prevailed on the Nigerian side during Maastrichtian times, when the Tethys sea extended to the south-east of the interior of western Africa. This resulted in the deposition of evaporite-bearing shales, the Dukamaje Formation, well known for its reptilian and fish remains. The localities described by Kogbe (1989) contain abundant arenaceous foraminifera but an extremely limited calcareous microfauna. Pelagic foraminifers are absent in these sediments; attesting to the shallow and marginal conditions under which sedimentation took place.

Following a mild regression of Danian-Montain age, a transgressional maximum occurred in the late Paleocene (Thanetian), which resulted in a marly, limestone lithofacies, the Kalambaina Formation. This formation is underlain and overlain by gypsiferous grey shale. The bottom shale, the Dange Formation, contains vertebrate remains, and the foraminiferal assemblage is entirely arenaceous and rather impoverished. The ostracod fauna, reported by Kogbe (1972) from the subsurface, supports a late Paleocene age for the Dange Formation and further indicates that there is no real age difference between the Dange, Kalambaina and Gamba Formations. The arenaceous microfauna would support a lithofacies interpretation that the Dange Formation is the transitional facies equivalent of the open marine calcareous Kalambaina Formation. The contact between the Dange and Kalambaina Formations is gradational and well-exposed on the slopes of the ridge at the northern extremity of Sokoto Basin. The lithologic change is marked by a gradual increase in the lime content. These lower marls contain the richest microfauna of the Kalambaina Formation. This is a shallow-water benthic foraminiferal assemblage dominated by larger rotaliids, nonionids and cibicidids. In addition, the overlying marls contain larger foraminifers that permit precise age assignment. Planktic foraminifers are absent. The thinly laminated grey shales of the formation bear a striking similarity to the Dange shales and overlie the Kalambaina marly limestones conformably. The best exposure of this formation is at its type locality in the Kalambaina quarry. It represents the return to marginal marine conditions and the final withdrawal of the sea from the region.

The similarity of the ostracod assemblages between North Africa (Libya), the Sudan district (Mali, etc.), the Iullemmeden Basin and southern Nigeria (Reyment, 1965) confirms the existence of epicontinental seas during the Paleocene. The results of the study by Kogbe (1989) support the view that the southern Nigerian coastal basin was connected with the northern sea during the Paleocene through the Mid-Niger Basin and not via the Benue Trough as suggested some workers

Most workers on Saharan and sub-Saharan geology tend to agree on the existence of several transgressive periods during the Cretaceous when marine waters from the Tethys sea moved southwards into the African continent through the Sahara. Simultaneously, Atlantic waters from the Gulf of Guinea moved northwards through the Benue Trough in the Turonian, and most probably through the mid- Niger Basin in the Maastrichtian, to link up with the Tethys transgression somewhere in the Niger Republic (Furon, 1960; Reyment, 1966; Adegoke, 1969; Adegoke, 1972; Adeleye, 1975; Kogbe 1976; Offodile, 1976). According to Kogbe (1989), the Turonian seaway passed through the east of the Hoggar but field evidence seems to suggest that the seaway was gradually displaced westwards during the Senonian (Reyment, 1966). By the end of the Maastrichtian, it was restricted to the western fringes of the Hoggar as evidenced by the absence of marine deposits of Maastrichtian age east of the Hoggar and none as well in the Upper and Middle Benue where the continental Gombe and Lafia Formations were deposited, respectively. The absence of fossiliferous limestones with the diagnostic Cenomanian ammonite genus Neolobites in the Goa Trench and the abundance of representatives of this genus in well documented beds in the Tenere, Damergou and Adar Doutchi, all east of the Hoggar, constitutes excellent evidence in favour of an eastern passage for the Turonian transaharan seaway. It is still difficult to establish whether the Turonian sediments of the Damergou and Bilma were deposited in a sea extending from north Africa, or whether they derived from an extension of the sea stretching inland from the Gulf of Guinea. This difficulty does not however, eliminate the strong probability of a linkage of both waters during the Turonian (Kogbe, 1989). The Turonian transgression must have passed through the Benue Trough, as there is no record of any marine Lower Cretaceous sediments in the Mid-Niger and Sokoto Basins. In these basins continental deposition prevailed at this time with the deposition of the Illo and Gundumi Formations (Continental Intercalaire) in the Iullemmeden Basin.



Stratigraphic succession in the Nigerian Sector of the Iullemmeden Basin (Sokoto Basin)

6. The Mid-Niger (Bida) Basin

The Mid-Niger Basin otherwise known as the Bida Basin or the Nupe Basin is a NW-SE trending intracratonic sedimentary basin extending from Kontagora in Niger State of Nigeria to areas slightly beyond Lokoja in the south. It is delimited in the northeast and southwest by the basement complex while it merges with Anambra and Sokoto basins in sedimentary fill comprising post orogenic molasse facies and a few thin unfolded marine sediments (Adeleye, 1974). The basin is a gently downwarped trough whose genesis may be closely connected with the Santonian orogenic movements of southeastern Nigeria and the Benue valley, nearby. The basin is a NW-SE trending embayment, perpendicular to the main axis of the Benue Trough and the Niger Delta Basin. It is frequently regarded as the northwestern extension of the Anambra Basin, both of which were major depocentres during the third major transgressive cycle of southern Nigeria in Late Cretaceous times. Interpretations of Landsat images, borehole logs, as well as geophysical data across the entire Mid-Niger Basin suggest that the basin is bounded by a system of linear faults trending NW-SE (Kogbe et al., 1983). Gravity studies also confirm central positive anomalies flanked by negative anomalies as shown for the adjacent Benue Trough and typical of rift structures (Ojo, 1984; Ojo and Ajakaiye, 1989).

Previous studies on the geology of the Bida Basin were reported in Adeleye (1973) and the micropaleontological studies of Jan du Chene et al. (1978) which documented the palynomorph-foraminiferal associations including the interpretation of the paleoenvironments of the Lokoja and Patti Formations. Akande et al. (2005) interpreted the paleoenvironments of the sedimentary successions in the southern Bida Basin as ranging from continental to marginal marine and marsh environments for the Cretaceous lithofacies. Whereas the origin of the oolitic ironstones in the Bida Basin has been a principal subject of several workers (e.g. Adeleye ,1973; Ladipo et al., 1994; Abimbola, 1997), only few investigations have been made on the hydrocarbon prospectivity of the basin

Lithostratigraphy and Depositional Environments

The stratigraphy and sedimentation of Upper Cretaceous succession of the Bida Basin have been documented by Adeleye and Dessauvagie (1972) in the central parts of the basin around Bida. Four mappable stratigraphic unites are recognized in this area, namely, the Bida Sandstone (divided into the Doko Member and the Jika Member), the Sakpe Ironstone, the Enagi Siltstone, and the Batati Formation. These are correlatable with the stratigraphic units in the Southern Bida Basin (Fig. 19).

In the southern Bida Basin (which has been best studied), exposures of sandstones and conglomerates of the Lokoja Formation (ca. 300 m thick) directly overly the Pre-Cambrian to Lower Paleozoic basement gneisses and schists. This is overlain by the alternating shales, siltstones, claystones and sandstones of the Patti Formation (ca. 70–100 m) thick in the Koton-Karfi and Abaji axis and succeeded by the claystones, concretionary siltstones and ironstones of the Agbaja Formation.

Central/Northern Bida Basin

The Bida Sandstone

The Bida Sandstone is divisible into two members, namely the Doko Member and the Jima Member. The Doko Member is the basal unit and consists mainly of very poorly sorted pebbly arkoses, sub-arkoses and quartzose sandstones. These are thought to have been depositied in a braided alluvial fan setting. The Jima Member is dominated by cross-stratified quartzose sandstones, siltstones and claystones. Trace fossils comprising mainly Ophiomorpha burrows have been observed. These were also observed in the overlying Sakpe Ironstone, suggesting a possible shallow marine subtidal to intertidal influence during sedimentation. The Jima Sandstone Member is thus considered as the more distal equivalent of the upper part of the Lokoja Sandstone, where similar features also occur.

The Sakpe Ironstone

The Sakpe Ironstone comprises mainly oolitic and pisolitic ironstones with sandy claystones locally, at the base, followed by dominantly oolitic ironstone which exhibits rapid facies changes across the basin, at the top.

The Enagi Siltstone

The Enagi Siltstone consists mainly of siltstones and correlates with the Patti Formation in the Lokoja sub-Basin. Other subsidiary lithologies include sandstone-siltstone admixture with some claystones. Fossil leaf impressions and rootlets have been found within the formation. The formation ranges in thickness of between 30m and 60m. Mineral assemblage consists mainly of quartz, feldspars and clay minerals.

The Batati Formation

This formation constitutes the uppermost units in the sedimentary sequence of the Bida Basin. The Batati Formation consists of argillaceous, oolitic and goethitic ironstones with ferruginous claystone and siltstone intercalations and shaly beds occurring in minor proportions, some of which have yielded nearshore shallow marine to fresh water fauna (Adeleye, 1973).

Southern Bida Basin

The Lokoja Formation

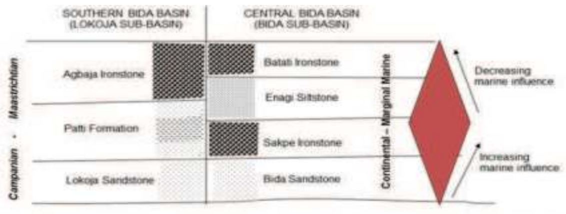
Lithologic units in this formation range from conglomerates, coarse to fine grained sandstones, siltstones and claystones in the Lokoja area. Subangular to subrounded cobbles, pebbles and granule sized quartz grains in the units are frequently distributed in a clay matrix. Both grain supported and matrix supported conglomerates form recognizable beds at the base of distinct cycles at outcrop. The sandstone units are frequently cross-stratified, generally poorly sorted and composed mainly of quartz plus feldspar and are thus texturally and mineralogically immature. The general characteristics of this sequence especially the fining upward character, compositional and textural immaturity and unidirectional paleocurrent trends, suggest a fluvial depositional environment dominated by braided streams with sands deposited as channel bars consequent to fluctuating flow velocity. The fine grained sandstones, siltstones and clays represent flood plain overbank deposits. However, Petters (1986) reported on the occurrence of some diversed arenaceous foraminifera from clayey interval of the Lokoja Formation indicating some shallow marine influence. These foraminiferal microfossils identified by Petters (1986) are however more common in the overlying Patti Formation where shallow marine depositional conditions are known to have prevailed more.

The Patti Formation

Outcrops of the Patti Formation occur between Koton-Karfi and Abaji. This formation consists of sandstones, siltstones, claystones and shales interbedded with bioturbated ironstones. Argillaceous units predominate in the central parts of the basin. The siltstones of the Patti Formation are commonly parallel stratified with occasional soft sedimentary structures (e.g. slumps), and other structures such as wave ripples, convolute laminations, load structures. Trace fossils (especially Thallasanoides) are frequently preserved. Interbedded claystones are generally massive and kaolinitic, whereas the interbedded grey shales are frequently carbonaceous. The subsidiary sandstone units of the Patti Formation are more texturally and mineralogically mature compared with the Lokoja sandstones. The predominance of argillaceous rocks, especially siltstones, shales and claystones in the Patti Formation requires suspension and settling of finer sediments in a quiet low energy environment probably in a restricted body of water (Braide, 1992). The abundance of woody and plant materials comprising mostly land-derived organic matter, suggests prevailing fresh water conditions. However, biostratigraphic and paleoecologic studies by Petters (1986) have revealed the occurrence of arenaceous foraminifera in the shales of the Patti Formation with an assemblage of Ammobaculites, Milliamina, Trochamina and Textularia which are essentially cosmopolitan marsh species similar to those reported in the Lower Maastrichtian marginal marine Mamu Formation (the lateral equivalent) in the adjacent Anambra Basin (Gebhardt, 1998). Shales of the Mamu Formation on the south side of the Anambra Basin are commonly interbedded with chamositic carbonates and overlain by bioturbated siltstones, sandstones and coal units in coarsening upward cycles towards the north side of the basin (Akande et al., 1992). This sequence is overlain by herringbone crossbedded mature sandstones of the Ajali Formation (Middle Maastrichtian) in the northern fringes of the basin hence providing strong evidence for shallow marine, deltaic to intertidal depositional environments for the Maastrichtian sediments of the Anambra Basin. The Patti Formation therefore appears to have been deposited in marginal shallow marine to brackish water condition identical to the depositional environments of similar lithologic units of the Mamu and Ajali Formations in the Anambra Basin (Ladipo, 1988; Adeniran, 1991; Nwajide and Reijers, 1996). The more marine influences in the adjacent Anambra Basin is probably related to the nearness of that basin to the Cretaceous Atlantic Ocean prior to the growth of the Niger Delta.

The Agbaja Formation

This formation forms a persistent cap for the Campanian - Maastrichtian sediments in the Southern Bida Basin as a lateral equivalent of the Batati Formation on the northern side of the basin. It consists of sandstones and claystones interbedded with oolitic, concretionary and massive ironstone beds in this region. The sandstones and claystones are interpreted as abandoned channel sands and overbank deposits influenced by marine reworking to form the massive concretionary and oolitic ironstones observed (Ladipo et al., 1994). Minor marine influences were also reported to have inundated the initial continental environment of the upper parts of the Lokoja Sandstone and the Patti Formation (Braide, 1992; Olaniyan and Olobaniyi, 1996). The marine inundations appear to have continued throughout the period of deposition of the Agbaja ironstones in the southern Bida Basin (Ladipo et al., 1994).



Stratigraphic succession in the Mid-Niger Basin (also known as Bida or Nupe Basin)

7. The Dahomey Basin

The Dahomey Basin is a combination of inland / coastal / offshore basin that stretches from southeastern Ghana through Togo and the Republic of Benin to southwestern Nigeria. It is separated from the Niger Delta by a subsurface basement high referred to as the Okitipupa Ridge. Its offshore extent is poorly defined. Sediment deposition follows an east-west trend. In the Republic of Benin, the geology is fairly well known (Billman, 1976; De Klasz, 1977). In the onshore, Cretaceous strata are about 200 m thick (Okosun, 1990). A non-fossiliferous basal sequence rests on the Precambrian basement. This is succeeded by coal cycles, clays and marls which contain fossiliferous horizons. Offshore, a 1000-m thick sequence consisting of sandstones followed by black fossiliferous shales towards the top has been reported. This was dated by Billman (1976) as being pre-Albian to Maastrichtian. The Cretaceous is divisible into two geographic zones, north and south. The sequence in the northern zone consists of a basal sand that progressively grades into clay beds with intercalations of lignite and shales. The uppermost beds of the Maastrichtian are almost entirely argillaceous. The southern zone has a more complicated stratigraphy with limestone and marl beds constituting the major facies.

Sedimentation in the northern zone which is located inland and close to the basin periphery, began during the Maastrichtian when a thin sequence (<200 m) of unconsolidated sands, grits, silts, clays and shales, was deposited. This sequence rests on the basement; the transitional facies is marked by a basal conglomerate or white to grey sandy and kaolinitic clays derived as degradation products from the surrounding Precambrian rocks.

In the southern zone, which is coastal and offshore, the oldest sediments consist mainly of loose sand, grits, sandstones and clay with shale interbeds which progressively grade into shale. They are late Albian and possibly Neocomian in age (Omatsola and Adegoke, 1981). The basal conglomerates have been reported from outcrops and boreholes (Jones and Hockey, 1964; Omatsola and Adegoke, 1981). The onshore sequence towards the basin periphery in Nigeria correlates well with the Maastrichtian onshore in the Republics of Benin and Togo. The geology of the Togo sector is very similar to that of Nigerian and Benin sectors. The Cretaceous succession shows marked lithological changes which have been expressed in terms of formal and informal lithostratigraphic nomenclature by previous workers (Fig. 22). This can lead to dual or multiple nomenclature and thus confusion.

Okosun (1990) carefully reviewed the stratigraphy of the Dahomey Basin. Little work has been published on the Cretaceous stratigraphy of the Dahomey Embayment. This is due in part to the confidentiality of oil company reports and the absence of readily available deep borehole cores. Jones and Hockey (1964) established the Abeokuta Formation for the Cretaceous sands, grits, clays and shale in the Nigerian sector. Reyment (1965) reported the occurrence of the Ajali Sandstone and the Nsukka Formation close to the basin margin around Ijebu-Ode and Okitipupa. He also reported the occurrence of Nkporo Shale in the subsurface of the basin. Billman (1976), from a study of some offshore sequences in the Republic of Benin, proposed two informal lithostratigraphic units: unnamed Older Folded Sediments and unnamed Albian Sands. The remaining portion of the Cretaceous sequence was referred to as the Abeokuta Formation, and the Awgu and Nkporo Shales. Jan du Chene et al. (1979), from a study of a coastal borehole (Ojo-1), reported the occurrence of strata of Albian to Maastrichtian age. Omatsola and Adegoke (1981) established three new, formal lithostratigraphic units, the Ise, Afowo and Araromi Formations, the first two of which correspond to the unnamed Older Folded Sediments and unnamed Albian Sands, respectively, while the Araromi Formation was considered equivalent to the Nkporo Shale of Billman (op. cit.). The Ise and Afowo Formations were dated as Neocomian (Valanginian) and Albian-Turonian respectively by these workers.

Stratigraphic Nomenclature

There has been a nomenclature problem in the stratigraphy of the Dahomey Basin. Jones and Hockey (1964) established the name Abeokuta Formation for the mainly arenaceous strata with mudstone, silt, clay and shale interbeds that crop out onshore. Billman (1976) subdivided the Abeokuta Formation into three lithostratigraphic units: the "Unnamed Older Folded Sediments", "Unnamed 'Albian Sands" and Abeokuta Formation. On the basis of age equivalence he referred the remaining Cretaceous strata to the Awgu and Nkporo Shales. Omatsola and Adegoke (1981) disagreed with this nomenclature on two main grounds. The first of these is that a rule of accepted stratigraphic practice is contravened because when the Abeokuta Formation was subdivided the same name was used for only one part of the succession. The second is that the application of the well-established Anambra Basin names: Nkporo and Awgu Shales to the Dahomey Basin solely on the basis of age is invalid. As a result, they proposed three new lithostratigraphic units, the Ise, Afowo and Araromi Formations, and referred these to the Abeokuta Group. In their classification, the Ise Formation is equivalent to the Unnamed Older Folded Sediments and the Unnamed Albian Sands, the Afowo Formation to the outcropping Abeokuta Formation, and the Araromi Formation to the Awgu and Nkporo Shales.

The view that Anambra Basin lithostratigraphic names should not be used in the Dahomey Basin solely on the basis of age was supported by Okosun (1990). Furthermore, it is inappropriate to use the same names for lithostratigraphic units situated in different basins which are both widely separated from each other and have had different geologic history. This is also true if material for comparison of complex lithologic sequences is only present in deep well cores that are not readily available for study. Thus the strata previously referred to as the Nkporo Shale were renamed Araromi Formation by Okosun (1990). The lithology of Ise and Afowo formations as defined by Omatsola and Adegoke (1981) show a high degree of similarity. Both are essentially sands and sandstones, but the latter contains thick interbeds of shale. This difference is not suficient to warrant the establishment of separate lithostratigraphic units. The two formations were considered synonymous by Okosun (1990). In that study, it was observed that the Ise, Afowo and Abeokuta formations have similar lithologic and electric log characters. The uppermost beds of Abeokuta Formation which crop out in the Ijebu-Ode area and in the shallow boreholes, at Itori, Wasimi and Ishaga onshore, consist mainly of fine- to coarse-grained sand and interbeds of shale, mudstone, limestone and silt. These lithofacies correlate well with the upper portion of the neostratotype in the Ojo-1 Borehole. studied by Okosun (1990). Although the Afowo Formation contains shale interbeds, Okosun (1990) emphasized that its essentially sandy character qualifies it along with the arenaceous Ise Formation, for inclusion in the Abeokuta Formation which also contains shale interbeds as demonstrated in the neostratotype described by him and as seen also in many surface outcrops. The use of the names Ise and Afowo Formations was therefore discontinued and replaced by the Abeokuta Formation which has priority of publication and a wider accepted usage. The Abeokuta Formation was defined by Jones and Hockey (1964) to consist of grits, loose sand, sandstone, kaolinitic clay and shale. It was further characterized as usually having a basal conglomerate or a basal ferruginised sandstone.

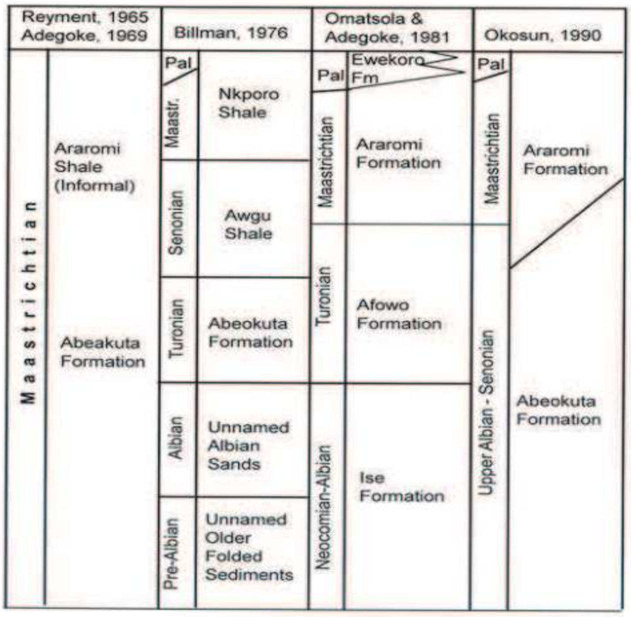


Fig. 22. Stratigraphic successions in the Dahomey Basin as variously erected by previous workers. The succession by Okosun (1990) is adopted in this work

8. The Niger Delta Basin

The Cenozoic Niger Delta is situated at the intersection of the Benue Trough and the South Atlantic Ocean where a triple junction developed during the separation of the continents of South America and Africa in the late Jurassic (Whiteman, 1982). Subsidence of the African continental margin and cooling of the newly created oceanic lithosphere followed this separation in early Cretaceous times. Marine sedimentation took place in the Benue Trough and the Anambra Basin from mid-Cretaceous onwards. The Niger Delta started to evolve in early Tertiary times when clastic river input increased (Doust and Omatsola, 1989). Generally the delta prograded over the subsidizing continental-oceanic lithospheric transition zone, and during the Oligocene spread onto oceanic crust of the Gulf of Guinea (Adesida et al., 1997). The weathering flanks of out-cropping continental basement sourced the sediments through the Benue-Niger drainage basin. The delta has since Paleocene times prograded a distance of more than 250km from the Benin and Calabar flanks to the present delta front (Evamy et al., 1978). Thickness of sediments in the Niger Delta averages 12km covering a total area of about 140,000km^2

Whilst the early Niger Delat is interpreted as being a river-dominated delta, the post-Oligocene delta is a typical wave-dominated delta with well-developed shoreface sands, beach ridges, tidal channels, mangrove and freshwater swamps. It is one of the world's largest deltas and shows an overall upward transition from marine shales (Akata Formation) through a sand-shale paralic interval (Agbada Formation) to continental sands of the Benin Formation. Depending on sea level changes, local subsidence and sediment supply, the delta experienced phases of regressions and transgressions. The stratigraphic framework and the detailed Tertiary stratigraphy of the Niger Delta are based on correlation of palynomorphs and foraminifera zones.

Stratigraphic Framework

The stratigraphic sequence of the Niger Delta comprises three broad lithostratigraphic units namely, 1) a continental shallow massive sand sequence – the Benin Formation, 2) a coastal marine sequence of alternating sands and shales – the Agbada Formation and 3) a basal marine shale unit- the Akata Formation. The Akata Formation consists of clays and shales with minor sand intercalations. The sediments were deposited in prodelta environments. The sand percentage here is generally less than 30%.

The Agbada Formation consists of alternating sand and shales representing sediments of the transitional environment comprising the lower delta plain (mangrove swamps, floodplain, marsh) and the coastal barrier and fluviomarine realms. The sand percentage within the Agbada Formation varies from 30- 70%, which results from the large number of depositional off lap cycles. A complete cycle generally consists of a thin fossilferous transgressive marine sand, followed by an offlap sequence which commences with marine shale and continues with laminated fluviomarine sediments followed by barriers and/or fluviatile sediments terminated by another transgression (Weber, 1972; Ejedawe, 1989).

The Benin Formation is characterized by high sand percentage (70-100%) and forms the top layer of the Niger Delta depositional sequence. The massive sands were deposited in continental environment comprising the fluvial realms (braided and meandering systems) of the upper delta plain.

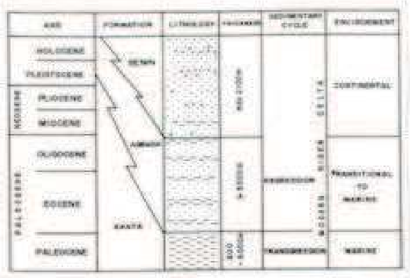
The Niger Delta time-stratigraphy is based on biochronological interpretations of fossil spores, foraminifera and calcareous nonnoplaknton. The current delta-wide stratigraphic framework is largely based on palynological zonations labeled with Shell's alphanumeric codes (e.g. P630, P780, P860). This allows correlation across all facies types from continental (Benin) to open marine (Akata). There have been concerted efforts, within the work scope of the stratigraphic committee of the Niger Delta (STRATCOM), to produce a generally acceptable delta-wide biostratigraphic framework (Reijers et al., 1997) but not much again has been accomplished after several data gathering exercise by the committee.

The sediments of the Niger Delta span a period of 54.6 million years during which, worldwide, some thirty-nine-eustatic sea level rises have been recognized (Adesida et al., 1997). Correlation with the chart of Garland et al. (1990) confirms the presence of nineteen of such named marine flooding surfaces in the Niger Delta. Eight of these are locally developed. Adesida et al (1997) defined eleven lithological mega sequences marked at the base by regional mappable transgressive shales (shale markers) that are traceable across depobelt boundary faults and proposed these as the genetic sequences that can be used as the basis for lithostratigraphy of the Niger Delta.

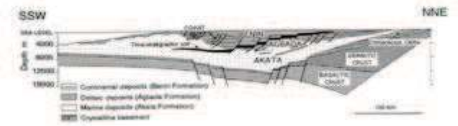
Structural Geology

The escalator regression model of Knox and Omatsola (1989) describes the one-way step-wise outbuilding of the Niger Delta through geologic time. The units of these steps are the depobelts. Depobelts, as defined therein, represent successive phase of delta growth. They are composed of bands of sediments about 30-60km wide with lengths of up to 300km. They contain major fault–bounded sequences which contain a shoreface alternating sand/shale sequence limited at the proximal end by a major boundary growth fault and at the distal end by a lithofacies change, a counter-regional growth fault, a major boundary fault of a succeeding depobelt, or any combination of these. Seawards, successive depobelts contain sedimentary fills markedly younger than the adjacent ones in a landward direction.

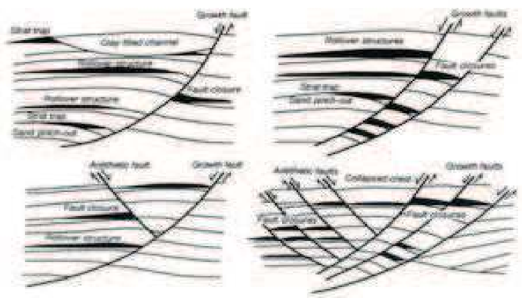
On a delta dip section, a relationship is apparent between successive depobelts. The base alluvial sand facies of an updip (older) depobelt is approximately time equivalent to the initiation of the base sand/shale sequence in the down-dip depobelt. The deposition of parallic sequences within any depobelt is terminated by a rapid advance of an alluvial sand facies over the proximal and central areas of the belt. This advance initiates deposition of the parallic sand/shales sequences in the succeeding depobelt. A parallic sequence develops in this new depobelt, and in the exterior part of the older depobelt, while the continental sands/gravels advance dischronously. This sequence of events repeated itself five to six times over the last 38 million years to define a series of depobelts in the Niger Delta. Five major depobelts are generally recognized namely, Northern Delta, Greater Ughelli, Central Swamp, Coastal Swamp, and Offshore. The most striking structural features of the Niger Delta are the large syn-sedimenatry growth faults, rollover anticlines and shale diapirs which deformed the delta complex (Evamy et al., 1978). The greater percentage of the oil fields in the Niger Delta is associated with rollover anticlines.



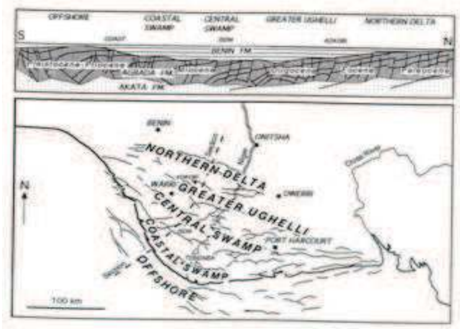
a) Stratigraphic succession in the Niger Delta



b) Stratigraphic succession, subsidence and progradational cycle model of the Niger Delta



c) Hydrocarbons are generally trapped in rollover anticlines and growth fault closures in the Niger Delta



d) Depo-belts of the Niger Delta

Stratigraphy, structural elements and modes of hydrocarbon occurrence in the Tertiary Niger Delta

PART THREE
MINERAL RESOURCES AND POLICY ISSUES

9. Solid Mineral Resources
Introduction

Nigeria as a nation is blessed with abundant solid mineral resources distributed fairly in all the states of the federation. According to reports by the Geological Survey of Nigeria Agency, Nigeria has some 34 known major mineral deposits distributed in locations across the country and offers considerable attraction for investors. Exploration in Nigeria for several solid minerals, e.g. tin, niobium, lead, zinc and gold, goes back for more than 90 years but only tin and niobium production have ranked on a world-wide scale. While the major international exploration groups have seldom paid more than a passing interest, there has been general exploration carried out by the tin mining groups and since the mid 1970s by several parastatal organizations and in particular the Nigerian Mining Corporation. Throughout its long history the Geological Survey of Nigeria Agency has played an active role in exploration for mineral deposits many of which have been first reported by its officers. The Geological Survey of Nigeria Agency has also been responsible for the regional mapping, airborne magnetic and radiometric surveys which provide an invaluable base for more detailed exploration. There is at present an upsurge of interest in the development of solid mineral resources whose production in the last 30 years has been declining in every case. The privatization, commercialization and general reform exercises currently being undertaken by the government of Nigeria are expected to lead to an upsurge in the exploration and development of Nigeria's solid mineral resources.

Solid Minerals in the Basement Complex Including the Younger Granites

Iron deposits

Three types of metamorphosed iron oxide rich layered metasediments are found in the NW and central parts of the Nigerian basement. The most important economically are those occurring within the Okene migmatite complex in south-central Nigeria. Mineable reserves of about 111,400,000 tonnes grading about 35 % Fe was repoted by Umunnakwe (1985) which could easily be upgraded and was subsequently partly developed for open pit mining to provide feed for the Ajaokuta steel complex close by. The most extensive occurrence of iron is in the form of Banded Iron Formation (BIF) in the Maru and Kushaka schist belts. The BIF occurs with fine grained pelitic sediments as thinly layered sedimentary rocks of probable chemogenic origin, often spatially associated with amphibolitic units. These deposits were investigated by the Geological Survey of Nigeria and National Steel Council in the 1960s and 1970s as potential iron ore sources but they were found to be low-grade (<30% Fe) and work was stopped. More recently a new discovery has been reported at the Muro Hills (Toto LGA, Nasarawa State) (Fig. 26), where within a hitherto unreported schist belt, a banded iron oxide quartz rock is associated with marble and dolomitic rocks (Obaje et al., 2006). Geochemical assessment of two representative BIF samples from the Muro Hills undertaken by the author at the Geological Laboratory of the University of Greifswald, Germany in 2008 gave iron content values of 43%. The iron ore occurs in association with a large deposit of marble which in places is almost pure dolomite. The presence of this marble is expected to enhance the prospects of mining the iron ore, which is also favourably disposed for open cast mining. Iron ore is one of the important minerals used in industry. Where Iron and Steel manufacture is undertaken, many secondary industries follow.

Gold and the Other Precious Metals

Though the precious metals are not essential for industrialization, they are a valuable source of foreign exchange and their exploitation to a large scale promotes the establishment of ancillary industries. In Nigeria traces of gold have been found in every area underlain by the Basement Complex and mining on a small scale has taken place in many areas. The Nigerian gold contains varying amounts of silver. Small amounts of silver are also present in the lead-zinc ores and this could probably be recovered as a by-product if the ore is mined on a sufficiently large scale.

Probably 90% of Nigeria's total gold production has been from alluvial deposits derived from primary gold mineralization in the basement rocks. All the producing areas have been in the western part of the basement where the schist belts are best developed and there is a spatial relationship with some schist belts although gold-quartz veins also occur in gneisses (e.g. Malele, Diko and Iperindo). Four gold fields can be outlined, Ilesha-Egbe, Minna-Birnin Gwari, Sokoto and Yelwa (Woakes and Bafor, 1983), and each covers several thousand square kilometers.

Tin-Tantalum-Niobium pegmatites

In terms of money values, the production of tin far exceeds that of any other solid mineral in Nigeria. Tantalum, niobium and other metals occur with the tin and have been produced as by-products. It is estimated that more than 95% of the over 650,000 tonnes of cassiterite (tin) produced has been from alluvial deposits derived from the Mesozoic Younger Granites. The remaining 5% of the tin has been derived from pegmatites which form a well defined ENE-WSW trending zone from the central Jos Plateau to the Ife-Ilesha area. Some pegmatites also contain gem quality corundum and are being mined on the Jos Plateau. This pegmatite zone was noted by Jacobson and Webb (1946) and later elaborated by Wright (1970). Both recognized that the pegmatites are older than the Mesozoic Younger Granites and linked them with the Pan-African Older Granite suite which often occurs in close proximity. However, Matheis and Vachette (1983) have distinguished barren and tin-bearing pegmatites where the latter are 100 Ma younger than the granites and barren pegmatites. They also point to the close association in Ilesha and Egbe area of tin-bearing pegmatites with schist belts and suggest metamorphic processes as important although Kinnaird (1984) relates them to late or post-Pan-African orogenic granites. Tin is believed to be one of the first metals used by man. In antiquity it was principally employed in making bronze and pewter, and later in lining cooking utensils. For many centuries it was one of the most important metals produced by man. Of its newer uses, the principal one is the manufacture of tinplated steel (tin plate), which finds universal employment in food-canning, the making of solder, type metal and collapsible tubes employs large quantities of tin, and it is also used in bearing metals. Its compounds are used in dyeing and fire-proofing.

Niobium (or columbium, as it is commonly termed in America) is a rare element with a high resistance to corrosion. It is almost always accompanied in its ores by varying amounts of the related elements tantalum. Its main use is in making certain heat- and corrosion-resisting steels that are at present principally used in gas-turbine engines. Because of its use in gas-turbine engines, niobium or tantalite has become a metal of vital strategic and industrial importance. Columbite, the ore of niobium, is a black mineral which is found in Nigeria with tinstone in alluvial deposits associated with the Younger Granites and Older Granites of the Plateau Tinfield. The columbite derived from the Older Granite pegmatites commonly occurs as massive dull, iron-black lumps and crystals, containing varying amounts of tantalum. The most important pegmatite deposits are found in the Wamba-Jema'a region of Nasarawa and Kaduna States. The high-grade columbite from the Younger Granites occurs in the form of small, black, platy crystals, averaging less than 0.03cm in length.

An Overview of the Solid Mineral Resources Distribution Map of Nigeria (Unlike petroleum, every State in the Federation has a fair representation of solid mineral deposits)

Samples of Tantalite deposits obtained from Andaha in Nasarawa State (b) Processed Columbite obtained from the Afu Younger Granite complex around Udege Beki in Nasarawa State

Chromite, Nickel, Talc and Asbestos

To date the only known occurrences of chromite and asbestos that are of interest are within the northwestern schist belts of Sokoto and Zamfara States where a well defined alignment of serpentinite bodies can be traced for 150 km from Ribah, through Tungan Kudaku and Maikwonaga to Sado. Another serpentinite body at Mallam Tanko lies 100 km east of the Sokoto linear and is an 8 km string of small bodies aligned N-S in gneisses but forming a southern projection of part of the Wonaka Schist Belt. There are reported cases of serpentinite occurrence in the Federal Capital Territory but yet to be properly mapped. The few available analyses indicate Cr_20_3 contents from 40-60% (Shibayan, 1985). Anthophyllite asbestos occurs commonly on the microscopic scale but larger veins are also found. Some derived soils of limited extent are enriched in nickel (Ogezi, 1977). A number of talc (with or without magnesite) bodies have been reported (Elueze, 1982) occuring in close relationship to the serpentinite.

Ni-sulphide and Base-metal deposits

Several authors (e.g. Bafor 1981, and Elueze 1981) have reported a variety of sulphide minerals including pyrite, pyrrhotite, pentlandite, bornite and chalcocite occurring in small amounts in gabbro intrusives and the metavolcanics of the schist belts. The Nigerian basement offers the possibilities of Ni-Cu-Sulphide minerals in magmatic synvolcanic bodies especially komatiites but also tholeiites. Klemm et al. (1984) described the Ilesha schist belt as having field and geochemical characteristics 'typical for Archaean granite greenstone terrains' contrary to the views of other workers that it represents an Upper Proterozoic sequence (Rahaman and Lancelot 1984). Klemm et al. (1984) went even further to identify komatiites (also known as metapyroxenites), within the amphibolite complex. Important Ni-sulphide ore deposits in the Archaean terrains of Australia, Canada and Zimbabwe are associated with the base of komatiite flows. Elsewhere in the schist belts the tholeiitic volcanics of the Maru, Kushaka and other schist belts might be comparable to the Pechanga (USSR), Lynn Lake (Canada) and other deposits world wide where some minor amounts of sulphides have been reported.

Within the Nigerian schist belts of the northwest, the dominance of clastic sediments over tholeiitic volcanics combined with the possible rift subsidence setting of the schist belts (Olade and Elueze, 1979) is indicative of a favourable environment for either the Besshi-Kieslager Cu-Zn type or for the exhalative Pb-Zn sedimentary type. The Nigerian schist belts may be compared to the Pan-African Damara Belt of Namibia (Martin, 1978) within which the Matchless Amphibolite Belt contains several Besshi-Kieslager type copper deposits such as the Otjihase (Goldberg, 1976). These deposits occur close to large volcanic masses within a thick sequence of clastic sediments and are associated with small bodies of exhalative iron formation and zones of strong chloritic alteration. The Nigerian schist belts contain such features and a more detailed search for Cu/Zn deposits guided by these criteria seems justified.

Manganese

Manganese deposits occur at Tudun Kudu within the Karaukarau Schist Belt west of Zaria in northwestern Nigeria. Muecke and Okujeni (1984) published detailed mineralogical studies in support of an epigenetic origin. The maganese occurrences of northwestern Nigeria have been variously described as 'conformable beds of quartzite' (Wright and McCurry, 1970), 'interbedded manganiferous quartzites within the phyllite' (Moneme et al., 1982) and as 'veins parallel to the foliation of the phyllites with sharp contacts' (Muecke and Okujeni, 1984). They are known to occur in only two of the schist belts, Maru (which also contains BIF, gold and amphibolites) and Karaukarau (which contains detrital quartzites but no iron-rich chemogenic quartzite, no gold and very minor amphibolites). Manganese is an essential substance in refining of steel. It acts principally by removing oxygen and sulphur from the molten metal.

Uranium

The possibility of finding uranium in Nigeria started to get more attention with the discovery of the mineral in bordering Niger Republic as well as the discovery of secondary uranium minerals in Cameroun. Recent studies have given stronger indications of the occurrence of uranium ore in some parts of the country. The first indications were registered in the results of the airborne radiometric surveys carried out by the International Resources Inc. U.S.A., in parts of the country. The radioactive anomalies refer mostly to the continental – paralic Cenomanian-Turonian deposits of the Bima, Keana, Makurdi and

Ezeaku Formations and the adjoining Basement and Younger Granite rocks. Uranium deposits in Nigeria could be peneconcordant or discordant. This implies that Nigeria's uranium ore could have been eroded from nearby source rocks, transported and concentrated in old river channels, fractures and other voids within the typically, fluviatile arkosic sandstones, or the basal micaceous sandstones of the host formations. Fossil organic matter (plant debris), which are potential precipitating agents, abound in these rocks. Alternatively, it could also be deposited by the secondary enrichment from the underlying igneous and basement rocks along the fracture zones in the arenaceous formations. Uranium, with niobium and thorium, occurs with pyrochlore in the Nigerian Younger Granite rocks. Pyrochlore is a constant accessory in the albite-riebeckite granite of the Younger Granite complex, which has a background of 10 -12 ppm Uranium (Bowden, 1982). The relationship between the Younger Granite rocks and the indicated uranium occurrences in the Cretaceous of the Benue Trough is not very clear. However, it has been shown, from current bedding analysis and other palaeogeographic studies that the detrital materials of the Cretaceous sediments originated from the surrounding Basement and Younger Granite rocks.

Industrial Mineral deposits

A variety of industrial mineral occurrences are found in the metamorphic terrain of the basement complex including marbles, talc, sillimanite, graphite and feldspar. Many of the Older Granites and other crystalline rocks are extensively quarried for road construction and building materials.

(i) Marble occurs within the migmatite-gneiss-schist-quartzite complex as relicts of sedimentary carbonate rocks. These are Upper Proterozoic schist belt metasediments which are normally marked by a general absence of carbonates. Several of these marble deposits are currently being exploited for cement (Ukpilla, Obajana) and decorative stone (Jakura, Kwakuti and Igbetti) with some production of ground rock for industrial use. Such marble deposits appear to be limited to the western portions of the south and central parts of the country. Large marble deposits occur in the Muro Hills and at Ugya in Toto Local Government Area of Nasarawa State. The deposits in these areas (Muro Hills and Ugya) are being mined sparingly and locally. The deposits are large enough to attract the attention of investment in cement manufacturing.

(ii) Talc is not yet exploited though there are many occurrences some of which are high grade though coloured. These deposits are associated with the amphibolites of the schist belts (Elueze, 1982) and further exploration may be expected to lead to commercial development.

(iii) Sillimanite occurrences in several schists (McCurry, 1976; Rahaman, 1976) have been reported. These occur as isolated higher grade metamorphic 'islands' within the generally low-grade facies schist belts of western Nigeria.

(i) Graphite occurs south of Jalingo in Taraba State, Northeastern Nigeria, where several extensive but low grade deposits have been reported in the basement rocks. In the Kushaka (Ajibade, 1980) and Maru (Egbuniwe, 1982) schist belts, graphitic slates and graphitic phyllites occur.

(v) Feldspars, both potash and soda varieties are exploited on a small scale for glazed ceramics in Suleja from pegmatites of the Older Granites suite. Further development of these and other deposits is possible.

(v) Mica: The mineral mica is quite common in the pegmatites of central Nigeria, but to be of value it has to be found in unbroken sheets several centimeters across, and must be free from inclusions. Some workable quantities of micas occur in Lokoja (Kogi State), Wamba, Gidan Kwano and Toto areas of Nasarawa State. White mica, or muscovite, is essential in the manufacture of many kinds of electrical equipment..

Gemstones

Most of the gemstones occur in pegmatites and quartz veins in rocks of the Basement Complex and Younger Granites. Like the precious metals, gemstones can be an important source of income for a developing country like Nigeria. There are many varieties of gemstones, too numerous to list here. Important ones in terms of quantity are aquamarine, emeralds, sapphire, ruby, topaz, tourmaline, zircon and almandine

A Marble mine at Ugya in Toto Local Government Area of Nasarawa State

Gemstones (Topaz, Aquamarine and Tourmaline) won from different localities in Nasarawa State. Gemstones are very common in many of the pegmatite veins in Nigerian basement complex rocks.

Solid Minerals in the Sedimentary Basins

Barytes

A study of the best known deposit of barytes at Azara in the Middle Benue Trough shows that the mineral infills fracture systems, but in generally arenaceous deposits. The fractures occur as single linear structures or as a series of irregular fractures interconnected and spaced over a considerable width and distance. In all, about 20 veins have been mapped in Azara, most of them represented by narrow, winding structures. Conservative estimates carried out in three rich veins, out of the 20 occurrences in this locality, indicated a reserve of up to 130 000 tonnes of contained $BaSO_4$, and for only 10 m depth. This reserve, excludes the biggest deposit, which for some unforeseen problems, were not incuded in the study by Offidile (1980). The indication is that the reserves could more than double this figure, as investigation continues. There are also other known occurrences in Keana, Gbande, and Abakaliki.

The importance of barytes in the oil, paint and paper industries is well known. At the present time, Nigeria imports a considerable quantity of this mineral for use in its oil-operations. Baryte is the chief constituent of lithopone paint and it is also extensively used as an inert volume and weight filler in drilling mud, rubber, glass, paper, etc. and in the chemical industry. Around Azara, other principal known occurrences are at Aloshi, Akiri, Wuse and Keana.

Barytes won from the Azara mines prepared for sale to receivers

Lead-Zinc

Lead-zinc (galena, sphalerite), often associated with baryte mineralization, is thought to be hydrothermal in origin. Fracturing and jointing are intense in the areas of mineralization. In places the structures are locally contorted, obscuring the regional geology. The mineralization consists essentially of siderite, sphalerite, galena and barytes assemblages with a minor amount of gold and silver. It is typical of the fracture-filling types. Over 30 lodes of lead-zinc with an aggregate length of about 7000 m have been reported in the Nigerian lead-zinc field. The mineralization was shown by drilling to be up to 100 m deep. In the Abakaliki area, in particular, lead-zinc mineralization was found associated with calcareous shales and shaly limestones. In the two occurrences at Ameri and Nyeba, the Nigerian Lead-Zinc Mining Company (1956) gave a conservative indicated ore reserve of 693 000 tonnes with 9.0% lead and 7.0% zinc. In the lead-zinc fields, two types of rocks are indentifiable, the galena and sphalerite rich rocks. The Abakaliki field is still Nigeria's most important lead-zinc deposit. Lead is used in the manufacture of cable coverings, pigments, storage batteries, solder, sheet lead and pipes, shot, and bearing metal. Other uses of zinc include galvanizing steel plate, the manufacture of brass and other alloys, rubber vulcanizing, and the production of pigments and certain medicines and chemicals.

Coal

Apart from spasely reported occurrences of lignites and minor sub-bituminous coals in the Sokoto Basin (Kogbe, 1976) and in the Mid-Niger Basin (Adeleye, 1989), all the coal deposits of Nigeria occur in the Benue Trough. Mineable coal deposits in Nigeria occur at Enugu, Okaba, Ogboyaga, Orukpa, Lafia-Obi, Gombe and Chikila. These coalfields fall into two main groups: the Turonian-Coniacian and the Campano-Maastrichtian coals. The Lafia-Obi coal deposit is geologically the oldest coal deposit in Nigeria so far discovered. This deposit is believed to be Turonian-Coniacian in age (Offodile, 1976, 1980; Obaje and Hamza, 2000). The Lafia-Obi coal seams are, unfortunately rather thin in outcrop, with the thickest seam only about 0.6 m. However, coal seams of up to 5m were encountered in the boreholes drilled by the National Steel Raw Materials Exploration Agency (Obaje, 1994). These coals are of high-medium volatile bituminous rank with vitrinite reflectivity in the range of 0.70 to 1.20%. The coals occur within the Awgu Formation and are widely exposed in outcrops along the bank of River Dep at Shankodi near Jangwa and in many boreholes drilled by the Steel Raw Materials Exploration Agency in the Obi-Agwantashi-Jangerigeri areas. These coal deposits have the highest rank among all Nigerian coal deposits and have been assessed to be suitable for coke making in steel manufacture, when slightly blended (Obaje, 1994, 1997). The Lafia-Obi deposit has estimated reserve of 22.4 million tonnes and the greater part of the deposit is yet to be fully explored. Jauro et al. (2007) also reported the occurrence of coals of high to medium volatile rank within the Lamja Formation in the Upper Benue Trough attributed to Turonian-Coniacian age.

The Mamu Formation in the Anambra Basin consists essentially of fine-grained sandstone, shale, mudstones and sandy shales with some coal-seams. Seam No. 3 (about 2 m) is worked by the Nigerian Coal Corporation in the Enugu and Orukpa areas of Enugu and Benue States respectively. The coals in the Gombe area were intercepted at shallow depths of about 15-35 m. The seams are generally thin, though one seam was reported to be up to 2 m thick. The rank is more or less lignitic and with a somewhat high ash content.

Much of Nigerian coals are consumed locally. Only about 110 000 tonnes per year are exported. The Lafia-Obi coal was expected to produce for the Ajaokuta steel complex at the rate of 50 000 tonnes per annum. Work on the project reached an advanced stage and beagn to slow down since the early 90's. The Enugu mines produced about 240 000 to 360 000 tonnes per annum as at 1980, and with the completion of the first phase of the mechanization programme of the Nigeria Coal Corporation, coal production rose to 1.6 million tonnes a year. The coal deposits are expected to provide the much needed energy for a number of cement factories and power stations planned in these areas. Coal production has been on the increase since 1970, despite the effects of the civil war and the dieselization of the Nigerian Railway Corporation. Moreover, the critical energy situation in the world, particularly in Nigeria, will make these relatively poor quality coals even more important in the economic development of the country.

Samples of Coal obtained from Shankodi near Jangwa in Nasarawa State; (b) A portion of surface exposure of the Shankodi Coal deposit . This coal has the highest rank (high- medium volatile bituminous rank) amongst the Coal deposits of Nigeria

Clays

Deposits of clays in mineable quantities occur in almost all the States of the Federation. Major deposits occur in Kankara in Katsina State, Naraguta (Jos) in Plateau State, Alkaleri in Bauchi State, Shabu and Lafia areas of Nasarawa State and at Ahoko near Lokoja in Kogi State. Clay is one of the earliest mineral substances utilized by man. It played an extremely important part in ancient civilizations, records of which were preserved in brick buildings, in monuments and in pottery, and as inscriptions upon claytablets. Clay is still an indispensable raw material today. The present uses of clay and clay products are too numerous to list completely. In domestic life, clay is used extensively in pottery, earthenware, china, cooking ware, vases, plumbing fixtures, tiles, porcelain wares and ornaments. In building, it is used for building bricks, vitrified and enameled bricks, tiles for floors, roofs, walls and drains, sewer pipes and as an ingredient of cement. In the electrical industry, it is used for conduits, sockets, insulators and switches. It is used on a large scale in making refractory ware, such as fire bricks, furnace linings, chemical stone ware, crucibles, retorts and saggars. From the practical point of view, the most important physical properties of clay are plasticity, shrinkage, fusibility and colour.

Limestone, Phosphates and Gypsum

The minerals, limestone, phosphate and gypsum are closely associated in the the sedimentary basins of Nigeria. Limestone-forming environments (shallow coastal marine conditions), appear to have occurred several times in the geological history of the basin. In all occurrences the deposition of this mineral is related to the transgressive and regressive cycles in the basins. The first Middle Albian transgression ended about the Cenomanian, marking its shorelines with the deposition of the limestones of the Odukpani Formation, at the Calabar flank, in the southeast. The Odukpani limestones are substantial in quantity and provide the raw material for the Calabar Cement Factory. At the Odukpani type section, two limestone beds, with thicknesses of about 25 m and 65 in, are exposed. The Late Cenomanian-Turonian transgression caused the deposition of the extensive limestone deposits, stretching from the southeast to the northeast. A number of limestone beds occur in the Ezeaku Formation of the Lower and Middle Benue, the Pindiga, Jessu and Dukul Formation of the Zambuk and Upper Benue areas of the northeast. The limestones of the Ezeaku Formation include the Nkalagu, Igumale, Makurdi, Gboko (Yandev) and the Akahana- Jangerigeri deposits, while those of the Pindiga/Jessu/Dukul Formations occur in Kanawa, Deba Habe, Jalingo and Ashaka. Recently large discoveries of limestone deposits were made near Awe in Nasarawa State and proposals for investment in cement production using these limestone deposits have been solicited from both the federal and the Nasarawa State governments. Most of the limestone deposits are high in quality, generally containing over 80% CaCO,. At Yandev, the main limestone bed is up to 35 m thick, and an indicated reserve of 68 million tonnes was estimated. Nearly all the limestone deposits in the country are used for the manufacture of cement.

Phosphate occurs in economic quantities within the Dukamaje Formation in the Sokoto Basin at Wurno and within the Kalambaina Formation at Dange and Shuni in the same basin. Occurrences in economic quantities have also been reported from the Dahomey Basin within the Ewekoro Formation in Southeastern Nigeria. Not much is known about the phosphatic beds associated with the top parts of the Pindiga Formation at Pindiga near Gombe. Carter et al. (1963) first reported the existence of this rock associated with the top part of the formation. Offodile (1976) has reported the occurrence of about 34 m of phosphatic clays and limestones with intercalations of gypsum at type locality of the Pindiga Formation in Pindiga. These beds were found to be directly overlain by the continental Gombe sandstones. The quality and lateral extent of the deposit is a subject for further investigation. Gypsum occurs with in close association with the phosphates in the Dukamaje Formation at Wurno and in the Dange Formation at Dange. Occurrences of gypsum have also been reported from Nafada and Potiskum in the Upper Benue Trough as well as from around Gboko in the Middle Benue Trough. The amount of gypsum normally collected, though not enough for export, are just enough to meet the demands of the local cement factories located in these localities.

Brine-fields/Salt deposits

The occurrence of brine-springs in the Benue Valley has attracted considerable attention. The most important seepages are found in the Abakaliki, Keana and Mutum Daya areas of the Lower, Middle and Upper Benue Trough respectively. Towns and villages around these localities have maintained a locally viable age-old trade, based on salt produced from the native salt refineries. The economic importance of the mineral in a country that imports more than 90% of its common salt and allied chemicals cannot be over-emphasized.

Most of the Benue brine-fields are underlain by formations of Cretaceous age. The tectonic set up in the three main fields (Abakaliki, Keana-Awe and Mutum Daya) is also similar. The Abakaliki, Keana-Awe and the Mutum Daya brine-fields are dominated by the Abakaliki, Keana and Lamurde anticlinoria. In each locality, brine-springs, are closely associated with these structures and are seen to issue from the flanks of the anticlinoria. The environments of deposition of the saline sediments of the Benue Trough are different from those of the South Atlantic basins. In the Gabon and Congo basins there is evidence of restricted access to the sea which allowed only an intermittent, but regular, supply of marine water into the basin, mainly in the Aptian to Albian, a condition favourable for the accumulation of evaporites. On the other hand, there is evidence of the existence of a positive basement barrier beneath the mouth of the present Niger Delta. It is not clear whether this feature could have restricted the movement of the sea both in and out of the valley, as in the South-West African basins. The indication is that the Benue sea-way maintained an open communication with the Atlantic throughout the Cretaceous. The parallel to subparallel folds are almost at right angles to the coast and these could not also have impeded the inflow of sea water during this time. However, the marine transgressive and regressive episodes were controlled, essentially, by tectonic and/or eustatic factors and evaporitic conditions appear to have developed, during the regressive phases when parts of the sea were cut off, with shoals and lakes forming in isolated areas under dry continental condition. Hydrochemical evaluation as presented in Tijani et al. (1997) pointed out that the evolution of the brine in the Benue Trough through the processes of evaporite formation and/or dissolution are less favored, while the source of the primary solution was said to be strongly linked to modified marine fossil seawater or formation water. The occurrences of the brines are in form of springs, dug-holes and salt ponds, which had been used for ages as the main raw material for local salt production within the associated communities.

Tar sands/Bitumen

Extensive geological and geophysical studies have shown the existence of huge deposits of tar-sands in Nigeria from which more than 31 billion barrels of heavy oil can be produced (Ogunsola and Williams, 1988). Heavy oils extracted from the Nigerian tar-sands are comparable in properties with those of that were imported earlier. The tar-sand is composed of sand, heavy oil (bitumen), mineral-rich clay and water in varying proportions. These proportions were found to be 84%, 12%, 2% and 4% respectively (Fasasi et al., 2003). This heavy oil in tar-sand is commonly referred to as bitumen. It is a viscous and complex mixture of hydrocarbons and other heterocyclic substances. Its formation could be due to thermal alteration, microbial degradation, water-washing or gas deasphalting. It may also be formed from radioactive bombardment (Fasasi et al., 2003). Extensive seepages of bituminous sand are known to occur along an East-West belt stretching over an area of about 120 km x 6 km across Lagos, Ogun, Ondo and Edo States in southwestern Nigeria. The Nigerian tar sands constitute important raw materials, like those that are needed by the Kaduna Refinery for the production of some non - conventional petroleum products such as lubricating greases, lubricating oil, waxes, bitumen and asphalt.

10. Petroleum Resources

Nigeria is the world's 8th largest producer and 6th largest exporter of petroleum. It is the largest producer and exporter on the African continent and is currently closely followed in production level by Angola, Libya and Gabon. Current reserves (as at 2008) are put at 35 billion barrels for oil and 180 trillion standard cubit feet for gas. At the moment production is entirely from fields in the Niger Delta region while exploration campaigns have been carried and/or ongoing in different segments of Nigeria's sedimentary basins.

The Niger Delta, offshore Dahomey Basin and some parts of the Anambra Basin constitute currently the oil province of Nigeria. The Niger Delta oil province is rated to be about the 12th largest in the world. Up to date a total of about 1182 exploration wells have been drilled with 1108 of them being on the delta. About 400 oil and gas fields of varying sizes have been documented. For the entire period of oil exploration and production in Nigeria, 51% of the exploration wells can be termed successful (570 discoveries for 1108 exploration wells). In the early years 52% of the exploration wells were successful and in the latter years the success rate increased to 68%. However, during a period of 1966-76 only 40% of the wells were considered successful. The increased success during the later years is attributed to improved seismic technology. The sizes of the fields have decreased over the period. Analysis of the discoveries shows that 3% of the discoveries are giants and represent 32% of the total reserves found. In retrospect, 40% of the discoveries represent smaller fields with only 3% of the total reserves found to date. Collectively, the giant fields produce in excess of 1 million barrels a day out of the nation's total production of about 2.1 million barrels per day. A giant oil field is classified as a field with an estimated ultimate recoverable oil of more than 500 million barrels. The giant fileds in Nigeria include Oso, Ubit, Assan, Meren, Abo, Bonga, Agbami, etc. The Bonga is located 120 kilometres (75 miles) offshore and has a daily production capacity of 200,000 barrels of oil and 150 million standard cubic feet of gas. Most Nigerian oilfields produce 20,000 to 40,000 barrels per day. Nigeria's average well produces 1000 barrels a day. Those fields with estimated recoverable oil in place of 30 million barrels and less are termed "marginal fields" and are hardly further developed by the major operating companies.

Within the inland basins of Nigeria, the Nigerian National Petroleum Corporation (NNPC) through its frontier exploration services arm (NAPIMS) drilled about 23 wells in the Nigerian sector of the Chad Basin and only gas shows were encountered. The first well in the Benue Trough region, Kolmani-River-1, drilled by Shell Nigeria Exploration and Production Company (SNEPCO) to a depth of about 3000m in 1999 encountered some 33 billion standard cubic feet of gas and little oil (that has been the only well drilled by that company in that area to date). Two other wells, Kuzari-1 and Nasara-1, drilled by Elf Petroleum Nigeria Limited (TotalFinaElf) in 1999 to a depth of 1666m and Chevron Nigeria Limited (ChevronTexaco) in 2000 to a depth of about 1500m, respectively, were reported dry.

Hydrocarbon Habitat of the Niger Delta

Almost all the commercial accumulations of oil and gas are found in deltaic sandstones of the Agbada Formation. The source of the hydrocarbons is attributed to generation from a combination of terrestrially and marine deposited organic matter in the underlying Akata Shale. Hydrocarbon accumulations are mainly related to growth fault structures where traps occur in dip-closed crestal areas or against one or more faults especially in their upthrown side. Growth faulting is induced by load, compaction and differential subsidence resulting from rapid sedimentation. In addition to conventional growth-fault related traps, there are other non-conventional stratigraphic traps related to channel fills, regional sand pinch-outs and truncation. Sand/shale ratios determine gross reservoir properties and sealing potential of faults.Transgressive marine shales form important regional top seals, whilst faults fequently form lateral seals. The sealing capacity of a fault is a function of the thickness and quality of shales that are juxtaposed across faults and the degree of smearing along the fault planes.

As a consequence of sand/shale alternations and the trapping mechanism, most fields are of a multiple reservoir type with stacked columns. Most of the reservoirs have column heights of up to 15m and in some cases column heights may be up to 50m. The majority of reservoirs do no appear to be filled up to split point. Gas-condensate-oil ratios are highly variable through the delta. High gas to oil ratios are found in the south central, eastern and northern part of the delta (Stacher, 1995). Gas chromatograms of whole crude and saturated compounds show variable oil compositions which indicate the differences in the environment of deposition of the related source rocks. Variations in pristane/phytane ratios are related to source rock environments changing from acid back-swamps with hardly any bacterial reworking to more aquatic, less acidic environments where bacteria rework algal and plant material to SOM (structureless organic matter). Wax content and pour points of non-biodegraded oils (API > 25°) are variable and depend on the quality of plant wax in the original source rocks. Variations in the composition of Niger Delta oils at low carbon numbers are as a result of biodegradation and gas/water flushing. Medium to heavy crudes (API < 25°) are usually biodegraded. Stacher (1995) observed that the vertical distribution of heavy degraded crudes directly relates to the thickness and depth of the freshwater continental sands of the Benin Formation. Contents of sulphur, nickel and vanadium of Nigerian crude oils are generally very low. Maturity indications for oil expulsion vary according to depobelt. This is in line with observations of the hydrocarbon distribution over the delta and suggests that individual macro-structures and depocentres form independent hydrocarbon provinces with their own burial, maturation, migration and trapping history.

Potentials in the Inland Basins

Some exploration campaigns have been undertaken in the inland basins of Nigeria with the aim to expanding the national exploration and production base and to thereby add to the proven reserves asset. The inland basins of Nigeria comprise the Anambra Basin, the Lower, Middle and Upper Benue Trough, the southeastern sector of the Chad Basin, the Mid-Niger (Bida) Basin and the Sokoto Basin. However, these inland basins have continued to frustrate the efforts of many explorers, principally because of the poor knowledge of their geology and the far distance from existing infrastructure (discovery must be large enough to warrant production investments), and for these reasons, many international companies have turned their focus away from frontier onshore to frontier deep-water and ultra deep-water offshore of the Niger Delta area.

The inland basins of Nigeria constitute one set of a series of Cretaceous and later rift basins in Central and West Africa whose origin is related to the opening of the South Atlantic. Commercial hydrocarbon accumulations were sometime ago discovered in Chad and Sudan within this rift trend. In SW Chad, exploitation of the Doba discovery (with estimated reserves of about 1 billion barrels of oil) has caused the construction of a 1070 km-long pipeline through Cameroon to the Atlantic coast. In the Sudan, some "giant fields" (Unity 1 & 2, Kaikang, Heglig, etc) have been discovered in the Muglad Basin (Mohamed et al., 1999). The major source rocks and reservoirs are in the Aptian-Albian-Cenomanian continental deposits of the Abu Gabra and Bentiu formations, respectively, which are similar and correlatable to the well-developed Bima Sandstone in the Nigerian Upper Benue Trough. In Niger Republic, oil and gas shows have also been encountered in Mesozoic - Cenozoic sequences in the East Niger Graben, which is structurally related to the Benue-Chad-Sudan-Libyan rift complexes (Zanguina et al., 1998). With relentless and re-invigorated geological and geophysical studies, particularly with respect to the evaluation of potential petroleum systems, commercial success can also be achieved in the Nigerian sector of Africa's inland basins, even if it may take some time to put all the elements together.

11. Policy Issues and Development Options

Solid Minerals

Prior to the emergence of petroleum in the mid nineteen seventies as a major foreign exchange earner, the solid minerals subsector ranked second only to the agricultural sector as a source of export earnings. The subsector also contributed substantially to national output, accounting for about 10 per cent of the GDP in 1970 (Kogbe and Obialo, 1976). The annual average output in the subsector was put at some 130.8 thousand metric tonnes over the years 1970 –1973. It employed, on the average, about 49 thousand workers per annum over the period 1958 – 1970. However, with the exit of foreign multinational mining companies and their expatriate professionals in the wake of the 1972 Indigenisation Decree, the performance of the subsector began to dwindle. Annual production declined considerably, particularly in metallic minerals. The tempo of mining activities shifted to industrial non-metallic minerals needed for construction, building and industrial applications in domestic industries.

Policy Evolution and Governance of the Sector

To a large extent, the performance of the solid minerals subsector has depended on the evolution of government policies over the years. Organised mining activities began in Nigeria between 1902 and 1923 following the commissioning in 1903 and 1904 of mineral surveys of the Southern and Northern Protectorates by the then British Secretary of State for the colonies. Modern mining of tin ore (cassiterite and associated minerals) was initiated by the Royal Niger Company in 1905. The mining of gold began in 1914 in areas located within present day Niger and Kogi States. Coal mining began at Enugu in 1916. By 1919, the Geological Survey of Nigeria was established as a department of government to take over and continue mineral surveys of the country.

The Minerals Ordinance of 1946 and the Coal Ordinance No. 29 of 1950 provided the legal basis for the development of solid minerals in Nigeria. The former vested ownership of all minerals in the British crown. It provides that "the entire property in land and control of minerals and mineral oils, in or under or upon any lands in Nigeria, and of rivers, streams and water courses throughout Nigeria, is and shall be vested in the state". The Minister of Mines and Power was empowered to grant prospecting and mining rights and leases to individuals and/or corporate organizations on application and payment of appropriate fees.

From the foregoing it is clear that the original cardinal principle of government's policy on prospecting and extracting mineral resources of the country on commercial basis was non-investment of public funds in the risk of mining investment. It was believed that investment in mining activities involved large sums of money on prospecting without any certainty of remunerative returns. The policy engendered a situation whereby large-scale foreign companies and small-scale indigenous miners concentrated their efforts on the production of minerals with export potential, neglecting minerals meant for local industries. Apart from coal which was mined by a government department, the mining of solid minerals was entirely in the hands of private expatriate and indigenous companies and entrepreneurs.

Prior to 1971, British mining companies dominated the scene with up to 120 companies at the peak of tin mining. These companies were well equipped. They employed qualified staff and paid detailed attention to efficiency considerations. All these combined contributed to large-sized output and employment. The Minerals Ordinance of 1946 and allied regulations which were re-enacted as the Minerals Act of 1959 applied globally to the exploration and exploitation of minerals without any particular distinction to special sets of minerals singly or in groups. However, as years passed, the development of mining particular minerals necessitated special regulations and led to the enactment of special Acts to govern the exploitation of special minerals. Such Acts included the Nigerian Coal Mining Act of 1950, the Gold and Diamond Trading Act, the Explosives Act of 1964, the Tin Act No. 25 of 1967, and the Quarries Act and Allied Regulations of 1969.

In 1971 the government policy on solid minerals was drastically reviewed. Government decided to act as catalyst in the mining sector through the establishment of mining corporations which would use government funds for mining. The main policy thrust was the rejection of the concept of private-sector-led development of the solid mineral subsector. Government was of the opinion that the objective of that ensuing mining policy would be to secure the development, conservation and utilisation of the mineral resources of Nigeria in the best possible manner so as to bring about economic benefit for the largest possible period, and that there was no reason to suppose that the private investor was the best instrument with which to achieve the objective. It thus meant that if prospecting and exploitation of minerals were to remain solely in the private sector, the country would be at a disadvantage.

To achieve the objectives of the new policy, government which had hitherto refrained from direct participation decided to participate directly in the mining industry. It established the Nigeria Mining Corporation (NMC) in 1972 to engage in direct investment in the exploitation of known economically viable minerals other than coal and marble. Through subsidiaries, the NMC engaged in the exploitation of kaolin, barytes, cassiterite, columbite, limestone and clays. The Nigerian Coal Corporation (NCC) was responsible for mining coal. Later the Nigerian Uranium Mining Company (NUMCO) was incorporated to mine and develop uranium.

Government direct involvement in the solid minerals subsector has been conducted through three parastatal organizations and an agency. Minerals like coal, iron ore and bitumen have always been under the complete control of government both in exploration and exploitation. In addition to the above parastatals (under the Ministry responsible for solid minerals) through which government exercised control and direct involvement, there are other parastatals whose activities interface with those of the former but which report to other Ministries. These include the Nigerian Iron Ore Mining Company (NIOMCO) which mines iron ore at Itakpe, the National Steel Raw Materials Exploration Agency (NSRMEA) which concentrates on exploration of iron ore and coking coals, the National Metallurgical Development Centre (NMDC) whose focus is on research in mineral processing and downstream utilization studies on minerals, all of which report to the Ministry of Power and Steel, and the Raw Materials Research and Development Council (RMRDC) located in the

Ministry of Science and Technology to source local raw materials-agricultural, forest, minerals and chemical-for domestic industries.

Despite the heavy public expenditure involved in the maintenance and operations of the above corporations, the expected economic advantages that informed the 1971 review of mining policy are still far from being realized.

With the exit of multinational companies and their expatriate professionals following the Indigenisation Decree of 1972, the bulk of mining operations by the private sector rested on the shoulders of small-scale indigenous miners. The surface, near surface and shallow depth deposits of the minerals had by then been variably depleted. These factors were largely responsible for production decline particularly in the metallic minerals. As a consequence, there was a shift of the tempo of mining activities to industrial non-metallic minerals needed for construction, building and industrial application for domestic industries. Furthermore, the downturn of the country's economy adversely affected the exploration as well as exploitation of even the non-metallic minerals. The Inspectorate Department of the Ministry of Mines and Power (as it was then known) was ill-equipped. It lacked adequate and suitable manpower to carry out surveillance of the minefields with a view to ensuring compliance to safety standards and to man the exit points to identify mineral commodities being exported. Illegal mining and speculative pegging by legal title holders were rife. These problems were further compounded by administrative bottlenecks which included cumbersome procedure in processing mining applications leading to long delays, difficulties in obtaining consent to enter land for the purpose of prospecting and mining, and procedural reports necessary for the approval of applications.

Current / Ongoing Reforms in the Solid Minerals Sector (As at 2008)

Below is a numerated summary of the ongoing reforms in the solid minerals sector (or subsector), which started since early 2005.

1. The Nigerian government considers the exploitation of Nigeria's mineral resources to be among its highest priorities, and it has said it is committed to the orderly development of these resources in a manner that guarantees the wealth and peace of all Nigerians.
2. The government also recognizes that the successful exploration and exploitation of Nigeria's mineral resources requires both technical expertise and financial strength that to a large extent can be provided by foreign investment capital.
3. A central platform for the new policy is the transformation of the role of government from that of owner-operator to administrator-regulator.

This is to allow the private sector to take a pivotal role in the growth of the mining sector.

4. To attract overseas investors, the government has said it is committed to fostering a stable regulatory, economic and political environment that encourages investors to make long-term commitments to exploration and development.
5. The principal legislation regulating mining activities in Nigeria is the Minerals and Mining Act 1999, which is currently administered by the Ministry of Mines and Steel Development. The 1999 Act has been reviewed and amended to ensure security of tenure of a mining title and greater transparency in licensing procedures.
6. Ownership of minerals is vested in the Federal Government of Nigeria as custodian on behalf of the citizens of the country. The government grants titles to allow suitable entities to explore for, mine and market mineral resources.
7. Fixed-term mineral titles over a specified area may be granted to entities committed to approved programmes of exploration or mining.
8. Applications for mineral titles and licences will be considered on a first-come, first-served basis and may be made by any person, at any time, over any area not covered by an existing title, or not otherwise reserved by the government.

It is therefore clear that government is making a return to privatization and private sector driven operations. Government and stake holders in the solid minerals sector identified the contraints in the immediate previous policy to include:

1. Lack of adequate data on mineral deposits up to bankable status.
2. Inadequate capital investments for private sector investors to participate in mining operations.
3. Lack of in-depth technological knowledge to develop and process the minerals.
4. Undue delay in the processing of mining applications.
5. Problems of air and water pollution as well as erosion and other ecological problems arising from mining activities.
6. Absence of a Mineral Resources and Environmental Management Committee in the States.
7. Basic infrastructures such as roads, electricity, and communication facilities at mining sites are grossly inadequate.
8. Lack of market channels for processed mineral products.

9. Absence of a Solid Minerals Development Bank or a window within the banking sector to support investments in the mining sector.

The following points can further be deduced from the current reforms in the sector:

The principle of derivation has been restressed as ownership of minerlas will still be vested in the Federal Government. A competitive business environment is to be created so that the private sector will be the driver of the operations. The role of government will be limited to regulation. Security of tenure for leasees will be guaranteed while discretionary allocation will be abolished. The interest of the community.will be protected. Government will continue to develop the political environment that will attract investors. Everybody will have a role to play: Local Governments, States and the Federal Government. Government may go into joint ventures with some private sector investors and above all the qualification criteria shall be "come one come all". It is further to deduce that Community Development Agreements will be entered into between the government, the community and the operator, which shall ensure adequate environmental protection and rehabilitation programmes. Furthermore it is expected that an Environmental Protection Fund will be established to ensure adequate Reclamation and proper Decommissioning. At the end of it all, government and stakeholders seem to have noted that mining of solid minerals may not be so volatile or crises-ridden as is the case with oil at the moment, but it can be if not properly handled.

Suggested Policy Modifications

Despite some noted setbacks in the policies guiding the exploration and production of oil and gas in Nigeria, government may still have to adopt a similar model to enable it derive maximum economic benefits from the solid minerals subsector. Below is a numerated summary of suggested inputs to that will guarantee a sustainable policy to the benefit of all stake-holders.

1. The Federal Government (on behalf of the Federation) shall continue to retain ownership of all minerals (solid, liquid and gaseous) in and under the land in the territory of the Federal Republic of Nigeria.
2. The Joint Venture (JV), Production Sharing Contract (PSC) and Sole Risk Operation (SRO) models as obtained in the oil and gas sector should be extended to the solid minerals sector.
3. The JV model shall comprise the Federal Government (40%), the State Government (20%), the Local Government (5%), and the private sector (core investor) (35%). There may be cases of straddled mineral deposits (i.e. those covering more than one state or more than one local government). In this case, the 20% or 5% as the case may be will be

contributed by the respective states or local governments. The JV model shall only be for the basis of raising initial capital and offsetting operational costs (cash calls). The private sector core investor shall be the operator. It should be noted that private sector core investor does not necessarily mean a foreign company, but it can also be.

4. All monies accruing from the operation (sales of the minerals / profits) shall go into the Federation Account from which a derivation of 50% should be retained in the Federation Account while the remaining 50% shall be returned on the basis of equity (40:20:05:35), after tax, if tax holidays had not been granted. Investments shall be for a specific mineral deposit in a particular locality which shall be ring-fenced in every particular case or for a leased area which may cover several minerals or for several leases but for which more than one contract have to be signed.
5. It would be noted in (4) above that a different derivation regime of 50% for the Federation Account is set for the solid minerals sector as against the current 87% (and 13% to the derivation-earning state) for oil and gas. It should however be noted that these are two different cases. The 50% going to the solid mineral producing state is not a derivation of any type but for equity participation for which the state is entitled to only 20%. The 50% in the Federation Account is for the Federal Government and all the states of the federation including the Federal Capital Territory. This should be so at the initial stage to attract investments into the sector while encouraging state governments to be proactive in seeking out investors themselves. When any solid mineral has attained a contributory quota of up to 30% of the nation's export earning or 10% of the Gross Domestic Product, the derivation to the Government of the Federation should be graduated upwards.
6. A National Solid Mineral Investments and Development Commission (NASCOM) should be set up to supervise the joint venture operations and shall have a state office in all states where JVs are in operation. The Federation Account Allocation Committee (FAAC), calling the attention of the NASCOM, shall ensure the return of the equity shares to the co-investors while the remaining 50% in the Federation Account will be shared between the Federal Government, the States and the Local Governments in line with the existing formula normally derived from the Revenue Mobilization, Allocation and Fiscal Commission (RMAFC).
7. Joint Ventures should initially be for specific minerals. It is recommended that at the initial stage they should be for gold, marble, limestone, baryte, lead-zinc, iron ore, coal and granite, but where these

co-exist with other minerals, as is the case in many geological environments, the agreement should cover all the minerals in the leased area.

8. All other operations should come under the PSC or Sole Risk models, for which the operator shall be on his own and shall fund the exploration and production. On deduction of initial capital (which shall be graduated over a specified period, e.g. 20 years) and periodic operational cost under the supervision of NASCOM, rest profit shall be shared between the operator, the Federal Government (on behalf of the Federation), the State Government (in this case derivation) and the Local Government (derivation) in a ratio that shall continue to encourage the operator to continue with investments.
9. For the purpose of Sole Risk agreements, the operator shall be solely responsible for all costs and shall be charged lincensing fees, royalties and profit taxes.
10. A State Government may wish to set up its own company to mine the mineral resources in its territory or any other territory in Nigeria for that matter. It should be allowed to do so but under the arrangement of either the JV or PSC as would be guided by NASCOM.
11. To make profits, there must be sales in the form of export or supply to local industries. It would be left for the operator and/or the joint venture partners to decide whether they want to establish downstream industries or identify downstream industries, belonging to a third party, that will absorb the mined raw materials. For example what do you do with so much limestone where there is no nearby located cement factory? Or what do you do with so much iron ore where there is no nearby located iron and steel company? But both are dependent one upon the other and each will determine the fate of the other which market forces will work out. However, export potentials are considerably large for all the mineral resources of Nigeria.

The suggested inputs are meant to serve as a mid-way between total privatization and total government control of the solid minerals sector, attract investors who may not have the abilty to bear all the financial burden alone (mining is a capital intensive venture), generate funds for all the tiers of government, expand the economy, generate employment, pacify communities but as well assisting them to take economic benefits of their resource endowments, reinforce federal ownership rights while dousing resource control agitations.

Specific Development Options Based on the Occurrence of Some Mineral Deposits in Nigeria

Based on the JV, PSC or Sole Risk models, the followings, amongst many others, are suggested options for the development of additional mineral-based industries in Nigeria to enhance economic growth and social transformation.

1. The development and recapitalization of the Ajaokuta Iron & Steel Company and the Associated Iron Ore Mining Company at Itakpe in Kogi State.
2. The establishment, or causing to be established, of additional Cement Manufacturing Companies at Ugya and Awe in Nasarawa State, Itobe in Kogi State, and Abuja in the Federal Capital Territory.
3. The establishment, or causing to be established, of Gold Mining Companies in Maru and Anka in Zamfara State, Zungeru in Niger State, Egbe in Kogi State, Birnin Gwari in Kaduna State, Bin Yauri in Kebbi State and Ilesha in Osun State.
4. The establishment, or causing to be established, of Salt Mining and Beneficiation Companies at Ribi and Awe in Nasarawa State.
5. The establishment, or causing to be established, of Small and Medium-Scale Tantalite and Associated Minerals Mining Enterprises at Wamba-Keffi-Nasarawa in Nasarawa State, Isanlu-Egbe in Kogi State, and Ijero-Aramoko-Ilesha areas in Ekiti and Osun States.
6. The establishment, or causing to be established, of Gemstone Mining, Collection, Processing and Marketing Centres at strategic localities in Kaduna, Plateau, Taraba, Bauchi, Nasarawa, Oyo, Ogun, Kogi, Kwara and Niger States.
7. The establishment, or causing to be established, of Coal Briquetting Companies at Obi (Nasarawa State), Enugu (Enugu State), Okaba and Ogboyaga (Kogi State), Orukpa (Benue State), and Gombe (Gombe State) to supply coal briquetters for domestic cooking all over Nigeria
8. Establishment, or causing to be established, of Independent Power Projects in above-listed coal localities to use the coal deposits for power generation for local consumption and/or supply/sale to the national grid.
9. The establishment, or causing to be established, of Barite Processing and Marketing Companies at Azara in Nasarawa State, Ugep in Cross River State, Wase in Plateau State and other localities in Benue, Taraba and Zamfara States.
10. The establishment, or causing to be established, of Sanitary Wares and Ceramic Industries in selected localities in Akwa Ibom, Anambra,

Bauchi, Ekiti, Imo, Katsina, Kebbi, Kogi, Ogun, Ondo, Plateau and Rivers States to use the abundant clay deposits in these areas as raw material.

11. The revival of the Cassiterite-Columbite Mining Company in Jos and the establishment, or causing to be established, of new ones in Bauchi, Cross River, Kaduna, Kano, Kwara and Nasarawa States.
12. The establishment, or causing to be established, of Glass Manufacturing companies in Delta, Jigawa, Kano, Lagos and Ondo States.
13. The establishment, or causing to be established, of Phosphate Processing Plants in Sokoto and Ogun States

Petroleum

Petroleum Legislation and Policy Evolution

Nigeria's petroleum legislation evolved piecemeal through what can be classified as the colonial, post-colonial, and post boom phases. Prominent among the colonial legislations were the Mineral Oils Act No. 17 of 1914; the Mineral Oils Act No. 17 of 1925; the Mineral Oils Act (Amendment) Ordinance 1959; and the Petroleum Profits Tax Ordinance 1959. Not only did these laws cede Nigeria's mineral rights to the British crown; they also reserved exploration and production rights to only British companies which for the mere payment of token rental due and royalties, acquired proprietary rights over all mineral deposits in the country.

Upon attaining sovereignty in 1960, ten petroleum-related laws were enacted within the first decade of independence. The most significant of these laws was the Petroleum Decree of 1969 (Decree No. 51). This was the nation's first comprehensive petroleum legislation, which covered among other things the definition of petroleum, land surface rights, rents, and compensation.

Apart from reducing the duration of an oil mining lease from the previous 30-40 years to 20 years, the 1969 decree was still, to a large extent, a bonanza to foreign operators. But after entering into membership of OPEC in 1971 and having established its own national petroleum corporation (the Nigerian National Oil Company) in 1972, Nigeria began to establish joint venture participation, production sharing and risk service interests with the oil companies. Between 1973 and 1974, the NNOC, which was later changed to the Nigerian National Petroleum Corporation (NNPC) in 1977, negotiated participation in all the major companies, thus acquiring large percentages in the operations of these companies.

The crash of oil prices in the world market in 1986, to below 10 dollars per barrel, rendered further exploration totally unprofitable to the foreign operators. The need, therefore, arose to offer them a new package of generous fiscal incentives to maintain the momentum in this strategic sector of the economy. This package is the Memorandum of Understanding which guaranteed to the oil companies a notional margin of 2.30 to 2.50 U.S dollars per barrel and a royalty of 2 U.S. dollars per barrel. Oil companies that operated under the various agreements include Shell, Exxon Mobil, Chevron, Elf, Nigeria Agip, Texaco Overseas, Express Petroleum/Conoco, Addax, Atlas, Amni International, Consolidated Oil, Pan-Ocean, Nigeria Petroleum Development Company, and Dubri Oil.

As an oil-exporting Third World nation, Nigeria's economic development has witnessed trials and tribulations, as the nation's fortunes have risen and fallen in the stormy seas of the international oil market. Nigeria's vulnerability to oil price shocks stems from the nation's over dependence on crude oil export. This is amply evident from the drastic decline in non-oil exports over the past three decades of petroleum production in Nigeria.

Crude oil accounted for 7.1 per cent of total exports in 1961, which was dominated at that time by cocoa, groundnut and rubber, in that order. In 1965, oil had climbed to 13.5 per cent of the nation's export earnings, and by 1970, it had become the leading source of foreign exchange, accounting for 63.9 per cent. The 1973 Arab oil embargo against the United States of America earned for Nigeria the windfall revenue of an oil boom. By 1979, petroleum sales had completely overshadowed non-oil exports, as it then contributed about 95 per cent of the country's export earnings and has remained so uptil date. During the peak of the oil boom, Nigeria's premium crude, the Bonny Light (37° API), fetched the commanding price of 40 dollars a barrel.

But by 1982, as a result of sustained recession in the western industrialised nations, stringent conservation and substitution measures, as well as increased crude production of non-OPEC countries, there was a glut in the international oil market. Consequently, the official price of the Bonny Light tumbled through 35 dollars a barrel in 1982 to 29.5 dollar per barrel in 1983 and then dipped below 10 dollars a barrel. Down too went the Nigerian economy, crashing along with petroleum prices. In spite of efforts to revamp the economy through the Structural Adjustment Programme, an economic package that included comprehensive non-oil export diversification initiatives, petroleum still held onto the level of 95 per cent of the nation's external earnings.

In 1990, following the Gulf War and the United Nations trade embargo on Iraq and Kuwait, not only did the Organisation of Petroleum Exporting Countries (OPEC) re-allocate the production shares of both nations to other producers such as Nigeria, there was also a sharp momentary increase in crude oil prices. From the low spot price of 15.49 dollars in June 1990, the average spot price of the Bonny Light soared to 36.78 dollars a barrel in August 1990. In 1993, the spot price of the Bonny Light, on the average, was about 18 U.S. dollars per barrel. As a result of expansions in the economies of China, India, and some other Asian countries, war in Iraq, apprehensions in Iran (over its nuclear programmes), restiveness in the Niger Delta region of Nigeria, average crude oil price in the international market as at June 2008 stood at 135 dollars. So strategic is the petroleum sector to the Nigerian economy that crucial aspects of this sec tor such as exploration, production, gas utilisation, conservation, and petroleum policy and legislation are sensitive economic issues. Also sensitive polit ically is the refined product pricing policy, especially subsidising energy prices.

The Federal Government's Policy goals for the upstream petroleum sector over the years, therefore, have been targeted at: Increaseing Crude oil output ; Increasing associated gas utilisation and consequently to end flarering; Encouraging greater foreign investment to finance E&P; Deregulation of petroleum products pricing; -Encouraging indigenous participation through the marginal fields and local content policies and Restoration of peaceful and cordial relations with Niger Delta oil-producing communties.

Current Policy Thrusts and Reforms in the Oil and Gas Sector

In April 2000, the Federal Government of Nigeria inaugurated a Committee, the Oil and Gas Sector Reform and Implementation Committee (OGIC), to advise it in the formulation of a new policy for the oil and gas sector of the economy. Government noted that its national oil company, the NNPC, had grown over the years to assume multiple and often times conflicting roles, including those of policy formulation, regulation, commercial operations and national assets management. It was also observed that the NNPC as a corporation had over the years evolved into a huge cost centre without the required strategic commercial focus. The corporation had been slowed down from performing its role as an integrated, commercial oil and gas company, especially as sister national oil companies were effectively competing against international oil companies in all spheres of the industry. It was also noted that the legal and governance structures that were designed for the sector since the 1970s could no longer cater for the requirements of a contemporary Nigerian industry. All government institutions in the industry were ill-equipped to carry out their functions in the complex and sophisticated industry. The most problematic, however, remains the NNPC. It has become simply a typical Nigerian parastatal that operates as huge amorphous cost centre with little or no sensitivity to the bottom line. The thrust of the new policy, therefore, was to revolve around the need to ensure separation and clarity of roles between the different public agencies operating in the industry. Equally important was the need to infuse strict commercial orientation.

The current structure of the industry is attached in the power point lay-out on the following pages. On the basis of government concerns and premise on the recommendations by the OGIC, government is in the process of unbundling the Nigerian National Petroleum Corporation and creating new agencies or strengthening some of its existing agencies as follows:

1. The National Petroleum Directorate (NPD) – May replace the Ministry of Petroleum Resources. Shall be the Secretariat of the Minister of Petroleum or Energy and shall be responsible for policy formulation in the sector.
2. The National Oil Company (NOC) – May take up any other name and shall replace the NNPC but shall be wholy capitalized to operate on strict commercial orientation.
3. The Petroleum Inspectorate Commision (PIC) – This will be an upgraded DPR (Department of Petroleum Resources) which shall be responsible for monitoring and regulation.
4. The Petroleum Products Distribution Agency (PPDA) – Shall concentrate on downstream operations, distribution and marketing on purely commercial basis.
5. The National Oil and Gas Asset Holding Company (NOAHC) – Shall replace the current NAPIMS (National Petroleum Investments Management Services) and shall continue the management and supervision of government interests in the joint ventures and production sharing agreements.
6. A National Petroleum Research Centre (NPRC) – May or may not be created; but if created it shall be responsible for national R & D in the sector.

It is important to stress here that the establishment of the proposed National Petroelum Research Centre that would have enabled the nation to derive maximun economic benefits from the oil and gas sector is long overdue. Nigeria experiences huge economic lost as a result of poor R&D culture in the industry (on the Nigerian side). Nigeria is currently the world's 8th largest producer of petroleum. Petroleum accounts for more than 90% of Nigeria's foreign exchange earnings; yet it has national research centres for everything but not for petroleum. R&D is the engine room on which every other business plan is based.

Upstream operations uptil now have been largely dominated by multinationals E&P companies (Shell, Chevron, Mobil, Elf, Agip, etc) and to a large extent have been liberalized and partly commercialized. The state (Nigeria) participates only through Joint Venture operations (JVs), Production Sharing Contracts (PSC), Sole Risk Agreements (SRA), rent collections and direct exploration by the NNPC through the NPDC (Nigerian Petroleum Development Company).

It is general knowledge that the Government never got its returns on investment on any of the JVs correctly because its company has never been the operator and the computations of taxes and accruable profits have been made so complex in some algebraic formulae that are understood only by a few persons in the industry. All the oils produced in Nigeria since 1958 have been produced by the multinational companies. NNPC has participated through JVs but it was never an active partner there. NNPC on its own has never been able to produce any significant amount of oil.

The exploration arm of our national oil company, NPDC in Benin (which should have been the core of NNPC) has been swinging in production level of between 5000 to 7000 barrels of oil per day compared to Shell's average of 500,000 bbpd and least of 100,000bbpd by any of the other multinationals. NNPC is not able to produce at home, even in the prolific Niger Delta, so it can seemingly not make any in–road into the international arena in the near future unless it embraces strong R&D policies.

In all, there is a big gap in research & development (R&D) on the Nigerian side in its quest to optimally exploit the petroleum resources of the nation for economic growth and social transformation. PDVSA of Venezuela has an engine room comprising 34 internationally renowned professors and industry experts (as at 2006), which acts as the strategic intelligent unit for its business decision. Information and data obtained from series of simulations, modeling, regional and acreage studies are normally passed over to its national oil & gas policy formulation agency and regulatory commission.

Shell has a very large R&D Centre in Rieswijk, the Netherlands. Chevron has an indomitable R&D Centre in San Ramon, USA. Ditto Mobil in Dallas, Total in Pau and Agip in Italy. Ironically, NNPC's R&D Centre is a shadow of itself in Port Harcourt.

To strategically place the NOC to be a successful exploration and production company in Nigeria and for it to make foray into other countries like other national oil companies such as Petrobras (Brazil), Petronas (Malaysia), PDVSA (Venezuela), Statoil (Norway), Saudi Aramco (Saudi Arabia) are doing, its R&D must be re-invigorated. This is normally a business decision but to cover for overall national interest, a National Petroleum Research Centre (NPRC) if established should work closely with the NPD and the PIC to assist these agencies in policy formulation and regulation of the industry. Some case studies as given below are sufficed to support the establishment of a National Petroleum Research Centre.

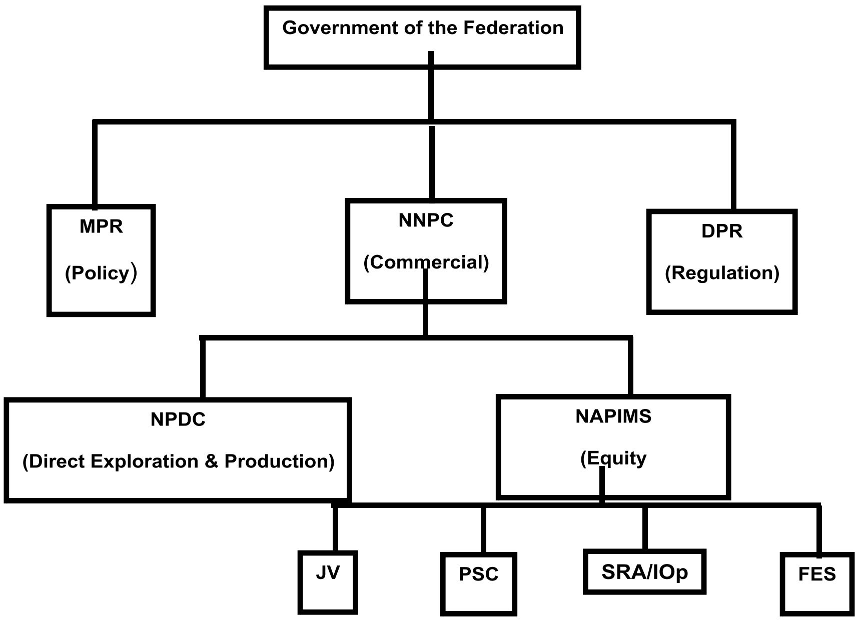
Case Study 1: Not long ago (around 1993), a block was won by Famfa Oil Company, an indigenous oil and gas exploration company. Famfa eventually sold off the block to then Texaco (now incorporated into Chevron) at a give away price. Texaco discovered that the block was very rich in oil (what the DPR did not know at the time it traded it off to Famfa). Texaco went ahead to discover the giant field of Agbami within the block. Later, NNPC (Government) wanted to buy in as a JV partner, what was not in the original agreement. A lot of controversies ensued and later resolved in some ways not very clear to industry watchers. A background simulation on the block through a strong research component would have assisted Government to derive value from the block during the bidding round process and avoided the unnecessary controversies that eventually trailed the operation of Agbami.

Case Study 2: There was also the case of the sale of a block (OPL 245) to Malabu Oil who later invited Shell to act as its technical adviser. On the discovery by Shell that OPL 245 held vast amount of oil in reserve, it eventually took over of the block through some back door policy. Series of legal tussles followed between Malabu Oil, the Government and Shell and it is still not clear how it ended and whether the case is now out of court. Who didn't know that OPL 245 was very prolific? Except DPR!!. Uptil now, has government gotten the economic value for OPL 245, even at the price offered by Shell?. The Research Centre should have been able to advise DPR (Government) approriately of the potentials of OPL 245 prior to the bidding round processes and many regional and specific acreage studies that would been carried out by the Research Centre would have been able to give a rough estimate of the value of OPL 245. Just like Shell did and refused to revert back to Malabu Oil.

Case Study 3: NNPC went into the Chad Basin on the Nigerian side and found nothing. Shell (through SNEPCO) went to the Upper Benue Trough, a trough structurally, geologically and geographically similar to the Chad Basin, and discovered some 33billion standard cubic feet of gas and a little oil under a team led then by Dr. Edmund Daukoru (then Shell's Exploration Manager and until recently, Nigeria's Energy Minister). Dr. Daukoru once told the author about how oils in horst and graben structures as in the Benue Trough and the Chad Basin could be very elusive compared to the easy-to-find oils in roll-over anticlines and growth fault structures in the Niger Delta and that it would take a lot of technology know-how and intense R&D to discover such oils as in the Chad Basin and Benue Trough. Uptil today that has been the singular moderate find in Nigeria's inland basins and that was by Shell.

All the above enumerated problems could easily have been overcome through studies on the "regional sand migration patterns over time using available well log data" by the Basinal / Acreage Assessment Section of the DPR/PIC. In this way, it is easy to estimate the prolificity of most of the acreages under consideration before the bidding-round process. Rigorous and sustained innovative research and development is an inevitable catalyst to improving performance and deriving maximum economic benefits from our national oil and gas sector business.

In Fig. 39 and through the attached Explanatory Note, the current structure of the industry is summarized and a brief introduction on the socio-political economy of the nation's oil and gas resources has been attempted.



Organizational Structure of the Oil & Gas Sector in Nigeria. Please note that the boxes are not necessarilly departments but operational structures. FES = Frontier Exploration Services. The diagram is also not a presentation of the NNPC organogram.

Explanatory Note 1

PETROLEUM RESOURCES

1. Petroleum, like all other mineral resources in Nigeria, belongs to the Government of the Federation; comprising the Federal Government, the Federating States (36 in number + the Federal Capital Territory), the Local Governments (774 in numbers) and the Producing Communities.

2. The Government of the Federation manages and participates in the Upstream and Downstream sectors of the petroleum industry through:
   a) Its national oil company – The NNPC – Commercial
   b) The Ministry of Petroleum Resources - Policy
   c) The Department of Petroleum Resources (DPR) – Regulation and Monitoring.

3. Major Roles of NNPC:
   a) Direct Exploration through the Nigerian Petroleum Development Company (NPDC).
   b) Joint Venture Operations and Equity Management through the National Petroleum Investments Management Services (NAPIMS) in the forms of:

   bi) Joint Ventures (JVs) – 60% NNPC (Nigerian Government), 40% Joint Venture Partners (Currently Shell, Mobil, Total, Chevron, Agip). Joint Venture Partners uptil now have been the Operators. Cost of operations and profits are shared according to equity interest.

   bii) Production Sharing Contracts (PSCs) – The company funds the operations until oil is found. Produced oil and profits are shared according to agreed formula.

   biii) Sole Risk Agreements / Indigenous Operators (SRA/IOp) – Usually a Nigerian owned company – The company will fund the operations and produce the oil and will pay for royalties and petroleum profit tax.

Explanatory Note 2

The Political Economy of Oil in Nigeria

1. All monies accruing from the sale and other commercial activities of petroleum in Nigeria are paid into the Consolidated Revenue Account or the Federation Account

2. Such monies are shared on monthly basis between the Federal Government, the State Governments and the Local Governments on determined ratios (usually determined by the Revenue Mobilization, Allocation and Fiscal Commission (RMAFC)

3. Presently 13% of the revenue derived from the receipt of oil produced from any State of the Federation is paid to that State. Currently there are nine (9) States enjoying such derivation revenue, namely: Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, Rivers.

4. Nonetheless, there is still some restiveness in the Niger Delta with some groups asking for an increase in the amount of derivation and some asking for outright resource control.

5. Whichever way, all tiers of government should work toward finding a lasting solution. This may not necessarily need increase in derivation but allowing some equity stake-holdings by the State and Local Governments as well as some indigenes of the locality where the petroleum is won and where the operating company is located. These stake-holdings should be built in the joint operating agreement to be operated by the core private sector investor (Shell, Mobil, Chevron, Total, etc).

Explanatory Note 3

But Is Nigeria Actually A Rich Country?

1. Oil accounts for 95% of the national foreign exchange earnings and about 80% of the GDP.

2. Current daily production stands at about 2.5 mbpd x current price of averagely $100 = $250 million.

3. There are 140 million people in Nigeria (as at 2008).

4. Poverty line is drawn to include all those living on less than $1 a day.

5. For Nigeria, all things being equal, every citizen can only earn $1.80 per day during good oil prices.

6. Deducting the monies needed to run governments and bureaucracies, Nigerians are still by all standards very poor.

Solution: Divest from oil and invest more in solid minerals, agriculture and technology development.

Conclusions

The Geology of Nigeria is made up of three major geological components, namely Basement Complex rocks (mainly Precambrian), Younger Granites (Jurassic) and Sedimentary Basins (Cretaceous – Recent). Petroleum occurs predominantly in Tertiary sequences of the Niger Delta sedimentary basin in southern Nigeria, with opportunities to add to the national petroleum reserve asset from further exploration in the inland basins. Petroleum is currently produced in 9 of the 36 Federating States in Nigeria. Solid minerals in different varieties and varying quantities and qualities occur in every of the Federating States in Nigeria. Petroleum accounts for about 95% of Nigeria's foreign exchange earnings and about 80% of the Gross Domestic Product but it does make Nigeria a rich state. Nigeria's economic performance can only be upgraded by a divestment from a monocultural oil economy to massive investments in solid minerals and agriculture. It has been suggested in this presentation that for Nigeria to be able to derive maximum economic benefits from its solid mineral sector, investments in the sector should be modelled after the Joint Venture, Production Sharing Contracts, and Sole Risk Agreements/Indigenous Operatorships as they obtain in the oil & gas sector, notwithstanding some setbacks noted in these models in the oil and gas sector. The role of research and development (R&D) had been greatly down-played in the Nigerian upstream oil and gas sector and hence the huge economic lost in the sector over the past years. For the nation to be able to derive maximum economic benefits from the oil and gas sector, its R&D component must be re-invigorated and strengthen, hence the need to establish a National Petroleum Research Centre.

Acknowledgements:

Immeasurable gratitudes are due to His Excellency, the Executive Governor of Nasarawa State, Alhaji Aliyu Akwe Doma, Garkuwan Doma, who has continued to encourage the author and the Department of Geology & Mining at the Nasarawa State University on different projects aimed at getting a better understanding on the geology and mineral resources of Nigeria and particularly of Nasarawa State. The Department of Geology & Petroleum Geology, University of Aberdeen (Scotland) through Dr. Mike Pearson and the Federal Institute for Geosciences & Natural Resources in Hannover (Germany) through Dr. Herman Wehner are gratefully acknowledged for assisting in the data generation over the past few years. The Royal Society of London, the German Academic Exchange Service-DAAD, the Alexander von Humboldt Foundation, the Alfried Krupp Wissenschaftskolleg Greifswald, the Shell

Petroleum Development Company of Nig. Ltd and the Management of Nasarawa State University Keffi are greatly appreciated for providing the financial supports for the respective projects on the subject matter.

Bibliography

Abaa, S. I. 1983. The structure and petrography of alkaline rocks of the Mada Younger Granite Complex, Nigeria. Journal of African Earth Sciences 3, 107-113.

Abimbola, F.A. 1997. Petrographic and paragenetic studies of the Agbaja Ironstone Formation, Nupe Basin, Nigeria. Journal of African Earth Sciences 25, 169–181.

Adeleye, D. R. and Dessauvagie, T. F. J. 1972. Stratigraphy of the Niger Emabyment near Bida, Nigeria. In: Dessauvagie, T. J. F. and Whiteman, A. J. (Eds), Proceedings of the Conference on African Geology, Ibadan University Press, Ibadan, pp181-186.

Adeleye, D. R. 1974. Sedimentology of the fluvial Bida Sandstones (Cretaceous) Nigeria. Sedimentary Geology 12, 1-24.

Adeleye, D. R. 1975. Nigerian Late Cretaceous stratigraphy and paleogeography. AAPG Bulletin 59, 2302-2313.

Adeleye, D. R. 1989. The Geology of the Mid-Niger Basin. In: Kogbe, C.A. (Ed.), Geology of Nigeria, 2nd ed. Elizabethan Publishing Co., Lagos, pp283–287.

Adeniran, B. V. 1991. Maastrichtian tidal flat sequences from the northern Anambra Basin, Southern Nigeria. Nigerian Association of Petroleum Explorationists (NAPE) Bulletin 6, 56–66.

Adeniyi, J. O. 1985. Ground total magnetic intensity in parts of the Nupe Basin and the adjacent basement complex, Niger State, Nigeria. Nigerian Journal of Applied Science 3, 67–78.

Adesida, A. A., Reijers, T. J. A and Nwajide, C. S. 1997. Sequence stratigraphic framework of the Niger Delta. Paper presented at the AAPG International Conference and Exhibition, Vienna, Austria.

Ajakaiye, D. E. 1983. Deep structures of alkaline ring complexes from geophysical data. Abstract, International Conference on Alkaline Ring Complexes in Africa. Zaria, Nigeria.

Ajayi, T. R. 1980. On the geochemistry and origin of the amphibolites in Ife-Ilesha area, SW Nigeria. Nigerian Journal of Mining and Geology 17, 179-196.

Ajibade, A. C., Fitches, W. R. and Wright, J. B. 1979. The Zungeru mylonites, Nigeria: recognition of a major unit. Rev. de Geol. Geog. Phys. 21, 359-363.

Ajibade, A. C. 1980. Geotectonic evolution of the Zungeru Region, Nigeria. Unpublished Ph.D. Thesis, University of Wales, Aberystwyth.

Ajibade, A. C., Rahaman, M. A. and Woakes, M. 1987. Proterozoic crustal development in the Pan-African Regime of Nigeria. ILP Working Group 3 Mid-term Report.

Akande, S. O., Hoffknecht, A. and Erdtmann, B. D. 1992. Rank and petrographic composition of selected upper Cretaceous and Tertiary coals of Southern Nigeria. International Journal of Coal Geology 20, 209–224.

Akande, S. O. and Erdtmann, B. D. 1998. Burial metamorphism (thermal maturation) in Cretaceous sediments of the Southern Benue Trough and Anambra Basin, Nigeria. AAPG Bulletin 82, 1191–1206.

Akande, S. O., Ojo, O. J., Erdtmann B. D. and Hetenyi, M. 1998, Paleoenvironments, source rock potential and thermal maturity of the Upper Benue rift basins, Nigeria. implications for hydrocarbon exploration. Organic Geochemistry 29, 531-542.

Akande, S. O. and Ojo, O. J. 2000. Organic petrology and Rock-Eval studies on source rocks facies of the Campanian-Maastrichtian Patti Formation, Southern Bida basin, Nigeria. Nigerian Association of Petroleum Explorationists Bulletin 16, 22-38.

Akande, S. O, Ojo, O. J., Erdtmann, B. D. and Hetenyi, M. 2005. Paleoenvironments, organic petrology and Rock-Eval studies on source rock facies of the Lower Maastrichtian Patti Formation, southern Bida Basin, Nigeria. Journal of African Earth Sciences 41, 394-406.

Allix, P., Grosdidier, E., Jardine, S., Legoux, O. and Popoff, M. 1981. Décoverte D'Aptien supérieur à Albien inférieur daté par microfossiles dans la série detritique Crétacé du fossé de la Benoué (Nigeria) C.R. Academy of Sciences Paris 2, 1291-1294.

AI-Shanti, A. L. S. and Mitchell, A. H. G. 1976. Late Precambrian subduction and collision in the AI Amar-Idsas region, Arabian Shield, Kingdom of Saudi Arabia. Tectonophysics 30, 41-47.

Annels, A. F. 1984. The geotectonic environment of Zambian coppercobalt mineralization. Journal of the Geological Society of London 141, 279-289.

Avbovbo, A. A., Ayoola, E. O. and Osahon, G. A. 1986. Depositional and structural styles in the Chad Basin of northeastern Nigeria. AAPG Bulletin 70, 1787-1798.

Bafor, B. E. 1981. The occurrence of sulphide mineralization in the Egbe area of southwestern Nigeria. Nigerian Journal of Mining and Geology 18, 175-179.

Barber, W. and Jones, D. C. 1965. The Geology and Hydrogeology of the Maiduguri Area, Borno Province. Geological Survey of Nigeria Bulletin.

Barker, C., Wang, L. and Butler, E. B. 1989. Distribution of bitumens in shales and its significance for petroleum migration. 15th International Meeting on Organic Geochemistry, Paris, France.

Benkhelil, J. and Robineau, B. 1983. Le fosse de la Benoue est il um rift? Centre Rech. Eplor. Prod. Elf Aquitaine Bulletin 7, 315-321.

Benkhelil, J. 1989. The origin and evolution of the Cretaceous Benue Trough, Nigeria. Journal of African Earth Science 8, 251–282.

Bennett, J. N. 1981. The petrology and mineral chemistry of the Shira ring complex, Northern Nigeria. Unpublished Ph.D. Thesis, University of St. Andrews.

Billman, H. G. 1976. Offshore stratigraphy and paleontology of the Dahomey Embayment. Proceedings, 7th African Micropaleontology Colloquium, lle-Ife.

Black, R. 1980. Precambrian of West Africa. Episodes 4, 3-8.

Black, R. and Girod, M. 1970. Late Paleozoic to Recent ignous activities in West Africa and its relationship to basement. structure. In: Clifford, T. W. and Gass, I. G.

(Eds), African Magmatism and Tectonics. Oliver and Boyd, Edinburgh, pp. 185-210.

Bowden, P., van Breemen, O., Hutchison, J. and Turner, D. C. 1976. Palaeozoic and Mesozoic Age trends for some ring complexes in Niger and Nigeria. Nature 259, 297-299.

Bowden, P. and Kinnaird, J. A. 1978. Younger Granites of Nigeria: a zinc-rich tin province. Transactions of the Institute of Mining and Metallurgy B 78, 66-69.

Bowden, P., Bennett, J. N., Kinnaird, J. A., Whitley, J. E., Abaa, S. I. and Hadzigeorgiou-Stravakis, P. 1981. Uranium in the Niger-Nigeria Younger Granite Province. Mineralogical Magazine 44, 379-389.

Bowden, P. and Kinnaird, J. A. 1984. Geology and mineralization of the Nigerian anorogenic ring complexes. Geologisches Jahrbuch (Hannover) B56, 3-65.

Bowden, P. 1985. The geochemistry and mineralization of alkaline ring complexes in Africa. Journal of African Earth Sciences 3, 17--39.

Braide, S. P. 1990. Petroleum geology of the southern Bida Basin, Nigeria. AAPG Bulletin 74, 617.

Braide, S. P. 1992a. Geologic development, origin and energy mineral resource potential of the Lokoja Formation in the southern Bida Basin. Journal of Mining and Geology 28, 33–44.

Braide, S. P. 1992b. Syntectonic fluvial sedimentation in the central Bida Basin. Journal of Mining and Geology 28, 55–64.

Braide, S. P. 1992c. Alluvial fan depositional model in the northern Bida Basin. Journal of Mining and Geology 28, 65–73.

Buchaman, M. S., Macleod, W. N., Turner, D. C. and Wright, E. P. 1971. The Geology of the Jos Plateau. Geological Survey of Nigeria Bulletin 32, 1-170.

Bungwon, A. D. 1983. The geology and preliminary soil geochemical investigation of possible gold bearing features in the Tserita-Tungan Kudaku area near Anka, Sokoto State. Unpublished M.Sc. Thesis, Ahmadu Bello University, Zaria, Nigeria.

Burke, K. C. and Dewey, J. F. 1972. Orogeny in Africa. In: Dessauvagie, T. F. J. and Whiteman, A. J. (Eds), Africa Geology. University of Ibadan Press, Ibadan, pp583-608.

Burke, K. 1976. The Chad Basin: an active intra-continental basin. Tectonophysics 36, 197–206.

Carter, J. D., Barber, W. Tait, E. A. and Jones, G. P. 1963. The Geology of Parts of Adamawa, Bauchi and Borno Provinces in Northeastern Nigeria. Geological Survey of Nigeria Bulletin 30, 108pp.

Chuku, D. U. 1981. Distribution of mineralization in the Nigerian Basement complex in relation to orogenic cycles and structural setting. Proceedings, 1st Symposium on the Precambrian Geology of Nigeria.

Dada, S. S. 1989.Evolution de la croute continental au Nord Nigeria: apport de la geochimie, de la geochronologie U-Pb et des traceurs isotopiques Sr, Nd et Pb. Ph.D. Thesis University of Science and Technology Languedoc, Montpellier, France.

Dada, S. S. 2006. Proterozoic Evolution of Nigeria. In: Oshi, O. (Ed), The Basement Complex of Nigeria and its Mineral Resources (A Tribute to Prof. M. A. O. Rahaman). Akin Jinad & Co. Ibadan, pp29-44.

Dahlkamp, F. J. 1978. Classification of Uranium deposits. Mineralogica Deposita 13, 83-104.
Dahlkamp, F. J. 1980. The time related occurrence of Uranium deposits. Mineralogica Deposita 15, 69-79.
De Klasz, I. 1977. The West African Sedimentary Basins. In: Moullade, M. and Nairn, A. E. M (Eds), The Phanerozoic Geology of the World. The Mesozoic 1. Elsevier, Amsterdam, pp. 371-399
Dessauvagie, T. F. J. 1975. Geological Map of Nigeria, 1:1,000,000 with Explanatory Notes. Journal of Mining and Geology 9, 1 -12.
Doust, H. and Omatsola, E. 1989. Niger Delta. AAPG Memoir 48, 201-238.
Egbuniwe, I. G. 1982. Geotectonic evolution of the Maru Belt, NW Nigeria. Unpublished Ph.D. Thesis, University of Wales, Aberystwyth.
Ejedawe, J. E. 1989. The Eastern Niger Delta: Geological Evolution and Hydrocarbon Occurrences. SPDC Internal Report, Exploration Note 89. 002.
Ekweozor, C. M. and Daukoru, E. 1984. Petroleum source bed evaluation of Tertiary Niger Delta; Reply. AAPG Bulletin 68, 391-394.
Elueze, A. A. 1981. Petrographic studies of metabasic rocks and meta-ultramafites in relation to mineralization in Nigerian schist belts. Journal of Mining and Geology 18, 31-36.
Elueze, A. A. 1982. Mineralogy and chemical nature of meta-ultramafites in Nigerian schist belts. Journal of Mining and Geology 19, 21-29.
Evamy, B. D., Haremboure, J., Kameling P., Knaap, W. A., Molloy, F.A. and Rowlands, P. H. 1978. Hydrocarbon Habitat of Tertiary Niger Delta. AAPG Bulletin 62:1-39.
Fairhead, J. D.and Blinks, R. M. 1991. Differential opening of the Central and South Atlantic Oceans and the opening of the Central African Rift System. Tectonophysics 187, 191–203.
Falconer, J. D. 1911. The Geology and Geography of Northern Nigeria. Macmillan, London.
Falconer, J. D. and Raeburn, C. 1923. The northern tinfields of the Bauchi Province. Geological Survey of Nigeria Bulletin 4.
Fasasi, M. K., Oyawale, A. A., Mokobia, C. E., Tchokossa, P. Ajayi, T. R. and Balogun, F. A. 2003. Natural radioactivity of the tar-sand deposits of Ondo State, Southwestern Nigeria. Nuclear Instruments and Methods in Physics Research A 505, 449–453.
Funtua, I. I., Onojah, A., Jonah, S. A., Jimba, B. W. and Umar, I. M. 1996. Radon emanation study of Uranium ore samples from NE Nigeria. Applied Radiation lsotopes 48, 867-869.
Furon R. 1960. Géologie de l'Afrique. Payot; Paris, 400pp.
Gandu, A. H., Ojo, S. B. and Ajakaiye, D. E. 1986. A gravity study of the Precambrian rocks in the Malumfashi area of Kaduna State, Nigeria. Tectonophysics 126, 181-194.
Garba, I. 1985. The geology and stream sediment prospecting for gold, Street 225, Isanlu, Kwara State. Unpublished, M.Sc. Thesis, Ahmadu Bello University, Zaria.

Gebhardt, H. 1998. Benthic foraminifera from the Maastrichtian lower Mamu Formation near Leru (Southern Nigeria): paleoecology and paleogeographic significance. Journal of Foraminiferal Research 28, 76–89.

Genik, G. J. 1992. Regional framework, structural and petroleum aspects of rift basins in Niger, Chad and Central African Republic (C.A.R.). Tectonophysics 213, 169–185.

Goldberg, I. 1976. A preliminary account of the Otjihase deposit, South West Africa. Economic Geology 71,384--390.

Grant, N. K. 1970. Geochronology of Precambrian basement rocks from Ibadan, south-western Nigeria. Earth and Planetary Sciences Letter 10, 19-38.

Grant, N. K., Hickman, M. H., Burkholder, F. R. and Powell, J. L. 1972. Kibaran metamorphic belt in Pan-African domainof West Africa? Nature 238, 90-91.

Grant, N. K. 1978. Structural distinction between a metasedimentary cover and an underlying basement in the 600 my old Pan-African domain of Northwestern Nigeria. Geological Society of America Bulletin 89, 50-58.

Holt, R. W. 1982. The geotectonic evolution of the Anka Belt in the Precambrian basement complex of N.W. Nigeria. Unpublished Ph.D. Thesis, The Open University.

Hubbard, F. H. 1975. Precambrian crustal development in Western Nigeria: Indications from Iwo Region. Geological Society of America Bulletin 86, 548-554.

Hubert, H. 1908. Mission Scientifique du Dahomey, Memeograpgh, Paris.

Idowu, J. O. and Enu, E. I., 1992. Petroleum geochemistry of some Late Cretaceous shales from the Lokoja Sandstone of Mid-Niger Basin, Nigeria. Journal of African Earth Sciences 14, 443– 455.

Idowu, J. O. and Ekweozor, C. M. 1993. Petroleum potential of Cretaceous shales in the Upper Benue Trough, Nigeria. Journal of Petroleum Geology 21, 105-118

Ike, E. C. 1979. The Structure, Petrology and Geochemistry of the Tibchi Younger Granite Ring Complex, Nigeria. Unpublished Ph.D. Thesis, University of St. Andrews.

Ike, E. C. 1983. The structural evolution of the Tihchi ring complex: a case study for the Nigerian Younger Granite province. Geological Society of London 140, 781-788.

Jacobson, R. R. E. and Macleod, W. N. 1977. Geology of the Liruei, Banke and adjacent Younger Granite ring complexes. Geological Survey of Nigeria Bulletin 33, 1-117.

Jan du Chene, R. E., Klasz, I de & Archibong, E. E. 1979. Biostratigraphic study of the borehole Ojo-1, SW Nigeria, with special emphasis on the Cretaceous microflora. Revue de Micropalaeontologie 21, 123-139.

Jan du Chene, R. E. 1980. Palynological study of the Tar Sand, Upper Maastrichtian of southwest Nigeria. Proceedings, 4th International Palynological Conference, Lucknow, pp794-799.

Jauro, A., Obaje, N. G., Agho, M. O., Abubakar, M. B. and Tukur, A. 2007. Organic geochemistry of Cretaceous Lamza and Chikila coals, Upper Benue Trough, Nigeria. Fuel 86, 520-532.

Jones, B. 1948. Sedimentary Rocks of Sokoto Province. Geological Survey of Nigeria Bulletin 18, 79pp.

Jones, M. P. 1953. Preliminary investigation of the occurrence of columbite in the Afu Hills Younger Granite complex. Geological Survey of Nigeria, Unpublished Report, No. 1114.

Jones, H. A. and Hockey, R. D. 1964. The geology of part of south-western Nigeria. Geological Survey of Nigeria Bulletin 31, 101pp..

Kinnaird, J. A. 1984. Contrasting styles of Sn-Nb-Ta-Zn mineralization in Nigeria. Journal of African Earth Sciences 2, 81-90.

Kinnaird, J. A. 1985. Hydrothermal alteration and mineralization of the alkaline anorogenic ring complexes of Nigeria. Journal of African Earth Sciences 3, 229 251. 1985.

Kinnaird, J. A., Bowden, P., Ixer, R. A. and Odling, N. W. A. 1985. Mineralogy, geochemistry and mineralization of the Ririwai complex, northern Nigeria. Journal of African Earth Sciences 3,185-222.

Klemm, D. D., Schneider, W. and Wagner, B. 1984. The Precambrian metavolcano-sedimentary sequence east of Ife and Ilesha, SW Nigeria. A Nigerian 'Greenstone belt'? Journal of African Earth Sciences 2,161-176.

Kogbe, C. A. 1972. Preliminary study of the geology of the Nigerian sector of the Iullemmeden basin. In: Dessauvagie, T. F. J. and Whiteman, A. J (Eds), African Geology. lbadan, University Press, Nigeria, pp219-228.

Kogbe, C. A. 1976. Paleogeographic history of Nigeria from Albian Times. In: Kogbe, C. A (Ed), Geology of Nigeria. Elizabethan Publishers, Lagos, pp15-35.

Kogbe, C. A. and Obialo, A. U. 1976. Statistics of mineral production in Nigeria (1946-1974) and the contribution of the mineral industry to the Nigerian economy. In: Kogbe, C. A (Ed), Geology of Nigeria. Elizabethan Publishers, Lagos, pp391-428.

Kogbe, C. A. 1981a. "Continental terminal" in the Upper Benue Basin of north-eastern Nigeria. Earth Evolution Series, Special Issue 1, 149-153.

Kogbe, C. A. 1981b. Cretaceous and Tertiary of the Iullemmeden Basin of Nigeria (West Africa). Cretaceous Research 2, 129-186.

Ladipo, K. O. 1986. Tidal shelf depositional model for the Ajali Sandstone, Anambra Basin, Southern Nigeria. Journal of African Earth Sciences 5, 177–185.

Ladipo, K. O. 1988. Paleogeography, sedimentation and tectonics of the Upper Cretaceous Anambra Basin, south-eastern Nigeria. Journal of African Earth Sciences 7, 865–871.

Ladipo, K. O., Akande S. O. and Mucke, A. 1994. Genesis of ironstones from the Mid-Niger sedimentary basin: evidence from sedimentological, ore microscopic and geochemical studies. Journal of Mining and Geology 30, 161-168.

Lambert, R. 1938. Echinides eocenes du Niger. Geological Society of France Bulletin 8, 77-86

Martin, H. 1978. The mineralization of the ensialic Damara Orogenic Belt. In: Verwoerd, W. J. (Ed), Mineralization in Metamorphic. Geological Society of South Africa, Special Publication No. 4, pp405-415.

Matheis, G. 1976. Short review of the geology of the Chad Basin in Nigeria. In: Kogbe, C. A. (Ed), Geology of NigeriaElizabethan Publishers, Lagos, pp289-294.

Matheis, G. and Caen-Vachette, M. 1981. Rb-Sr isotopic study of rare metal bearing and barren pegmatites in the Pan-African reactivation zone of Nigeria. Proceedings. 1st Symp. of the Precambrian Geology of Nigeria, Kaduna.

Matheis, G. and Caen-Vachette, M. 1983. Rb-Sr isotopic study of rar e metal bearing and barren pegmatites in the Pan-African reactivation zone of Nigeria. Journal of African Earth Sciences 1, 35-40.

McCurry, P. 1973. Geology of Degree Sheet 21, Zaria, Nigeria. Overseas Geology and Mineral Resources.

McCurry, P. 1976. The Geology of the Precambrian to Lower Palaeozoic Rocks of Northern Nigeria- A Review. In: Kogbe, C. A. (Ed), Geology of Nigeria. Elizabethan Publishers, Lagos, pp15-39.

McKelvey, V. E. and Balsley, J. R. Jr. 1948. Distribution of coastal black sands in N. Carolina, S. Carolina and Georgia, as mapped from an airplane. Economic Geology 43, 518-524.

Mohamed, A. Y., Pearson, M. J., Ashcroft, W. A., Illiffe J. E. and Whiteman, A. J. 1999. Modeling petroleum generation in the Southern Muglad rift basin, Sudan. AAPG Bulletin 83, 1943-1964.

Moneme, P. C., Scott, P. W. and Dunham, A. C. 1982. Managanese mineralization at Tudun Kudu, Zaria District, North-Central Nigeria. Nigerian Journal of Mining and Geology 19, 30-42.

Moumouni, A., Obaje, N. G., Nzegbuna, A. I. and Chaanda, M. S. 2007. Bulk geochemical parameters and biomarker characteristics of organic matter in two wells (Gaibu-1 and Kasade-1) from the Bornu Basin: Implications on the hydrocarbon potential. Journal of Petroleum Science and Engineering 58, 275–282.

Mpanju, F., Ntomola, S. J. Kagya, M. 1991. The source rock potential of the Karoo coals of the southwestern rift basin of Tanzania. Journal of Southeast Asian Earth Sciences 5, 91-303.

Muecke, A. and Okujeni, C. 1984. Geological and ore microscopic evidence on the epigenetic origin of the manganese occurrences in northern Nigeria. Journal of African Earth Sciences 2, 209-225.

Muecke, A. and Neumann, U. 1985. Are the iron ore deposits of Itakpe area of the Itabirite-type or the Itakpeite-type? Abstract, 21st Conference of the Nigerian Mining and Geosciences Society.

Murat, C. 1972. Stratigraphy and paleogeography of the Cretaceous and Lower Tertiary in South-eastern Nigeria. In: Dessauvagie, T. F. J. and Whiteman, A. J. (Eds.), African Geology. Ibadan University Press, pp251–266.

Nwajide, C. S. 1990. Sedimentation and paleogeography of the Central Benue Trough, Nigeria. In: Ofoegbu, C. O. (Ed), The Benue Trough Structure and Evolution. Vieweg, Braunschweig, pp19-38.

Nwajide, C. S. and Reijers, T. J. A. 1996. Sequence architecture in outcrops: examples from the Anambra Basin, Nigeria. Nigerian Association of Petroleum Explorationists Bulletin 11, 23–33.

Obaje, N. G. 1994. Coal petrography, microfossils and paleoenvironments of Cretaceous coal measures in the Middle Benue Trough of Nigeria. Tuebinger Mikropalaeontologische Mitteilungen 11,1-165.

Obaje, N. G. and Abaa, S. I. 1996. Potential for coal-derived gaseous hydrocarbons in the Middle Benue Trough of Nigeria. Journal of Petroleum Geology19, 77-94.

Obaje, N. G. and Ligouis, B. 1996. Petrographic evaluation of the depositional environments of the Cretaceous Obi/Lafia coal deposits in the Benue Trough of Nigeria. Journal of African Earth Sciences 22, 159-171.

Obaje, N. G. 1997. Petrographic evaluation of the coking potential of the Cretaceous Obi/Lafia coal deposits in the Benue Trough of Nigeria. Zeitschrift fur Angewandte Geologie 43, 218-223.

Obaje, N. G., Ulu, O. K. and Petters, S. W. 1999, Biostratigraphic and geochemical controls of hydrocarbon prospects in the Benue Trough and Anambra Basin, Nigeria. Nigerian Association of Petroleum Explorationists (NAPE) Bulletin 14, 18-54.

Obaje, N. G., Abaa, S. I., Najime, T. and Suh, C. E. 1999. Economic geology of Nigerian coals resources—a brief review. Africa Geoscience Review 6, 71–82.

Obaje, N. G. and Hamza, H. 2000. Liquid hydrocarbon source-rock potential of mid-Cretaceous coals and coal measures in the middle Benue trough of Nigeria. International Journal of Earth Sciences 89, 130-139.

Obaje, N. G., Wehner, H., Scheeder, G., Abubakar, M. B. and Jauro, A. 2004. Hydrocarbon prospectivity of Nigeria's inland basins: from the viewpoint of organic geochemistry and organic petrology. AAPG Bulletin 87, 325–353.

Obaje, N. G. 2005. Fairways and reservoir potential of Pliocene – Recent sands in the shallow offshore Niger Delta. Journal of Mining and Geology 40, 25-38.

Obaje, N. G., Lar, U. A., Nzegbuna, A. I., Moumouni, A., Chaanda, M. S. and Goki, N. G. 2006. Geology and Mineral Resources of Nasarawa State: An Investors's Guide. Nasara Scientifique (A publication of the Nasarawa State University) 2, 1-34.

Offodile, M. E. 1976. The geology of the Middle Benue, Nigeria. Palaentological Institute, University Uppsala, Special Publication 4, pp1-166

Offodile, M. E. 1980. A Mineral Survey of the Cretaceous of the Benue Valley, Nigeria. Cretaceous Research 1, 101-124.

Ogezi, A. E. O. 1977. Geochemistry and Geochronology of Basement Rocks from Northwestern Nigeria. Unpublished Ph.D. Thesis, University of Leeds.

Ogunsola, O. I. and Williams, P C. 1988. Particle size effects on compositional analyses of Nigerian tarsands. Journal of African Earth Sciences 7, 653-655.

Ojo, O. M. 1980. Prospects of finding uranium deposits in Nigeria. Nigerian Journal of Mining and Geology 17, 1-12.

Ojo, S. B. 1984. Middle Niger Basin revisited: magnetic constraints on gravity interpretations. Abstract, 20th Conference of the Nigeria Mining and Geosciences Society, Nsukka, pp52–53.

Ojo, S. B. and Ajakaiye, D. E. 1989. Preliminary interpretation of gravity measurements in the Mid-Niger Basin area, Nigeria. In: Kogbe, C.A. (Ed.), Geology of Nigeria, 2nd edition, Elizabethan Publishers, Lagos, pp347–358.

Ojoh, K.A. 1992. The southern part of the Benue Trough (Nigeria) Cretaceous stratigraphy, basin analysis, paleo-oceanography and geodynamic evolution in the equatorial domain of the South Atlantic. Nigerian Association of Petroleum Explorationists (NAPE) Bulletin 7, 131-152.

Okosun, E. A. 1990. A review of the Cretaceous stratigraphy of the Dahomey Embayment, West Africa. Creaceous Research 11, 17-27.

Okosun, E. A. 1992. Cretaceous ostracod biostratigraphy from the Chad Basin in Nigeria. Journal of African Earth Sciences 14 (3), 327–339.
Okosun, E. A., 1995. A review of the geology of the Bornu Basin. Journal of Mining and Geology 31 (2), 113–122.
Olade, M. A. 1978. General features of a Precambrian iron ore deposit and its environment at Itakpe ridge, Okenne, Nigeria. Transactions of the Institute of Mining and Metallurgy 86, B1-B9.
Olade, M. A. and Elueze, A. A. 1979. Petrochemistry of the Ilesha amphibolite and Precambrian crustal evolution in the Pan-African domain of SW Nigeria. Precambrian Research 8, 303-318.
Olaniyan, O. and Olobaniyi, S. B. 1996. Facies analysis of the Bida Sandstone Formation around Kajita, Nupe Basin, Nigeria. Journal of African Earth Sciences 23, 253–256.
Olarewaju, V. O. 2006. The Charnockitic Intrusives of Nigeria. In: Oshi, O. (Ed), The Basement Complex of Nigeria and its Mineral Resources (A Tribute to Prof. M. A. O. Rahaman). Akin Jinad & Co. Ibadan, pp45-70.
Olayinka, A. I. 1992. Geophysical siting of boreholes in crystalline basement areas of Africa. Journal of African Earth Sciences 14, 197-207.
Olugbemiro, R. O., Ligouis B. and Abaa, S. I. 1997. The Cretaceous series in the Chad basin, NE Nigeria: Source rock potential and thermal maturiy. Journal of Petroleum Geology 20, 51-68.
Omatsola, M. E. and Adegoke, O. S. 1981. Tectonic evolution and Cretaceous stratigraphy of the Dahomey Basin. Journal of Mining and Geology 18, 130-137.
Oshin, I. O. and Rahaman, M. A. 1986. Uranium favourability study in Nigeria. Journal of African Earth Sciences 5, 167-175.
Oyawoye. M. O. 1972. The Basement Complex of Nigeria. In: Dessauvagie, T. F. J. and Whiteman, A. J. (Eds.), African Geology. Ibadan University Press, pp66-102.
Petters, S. W. 1978. Middle Cretaceous paleoenvironments and biostratigraphy of the Benue Trough, Nigeria. Geological Society of America Bulletin 89, 151–154.
Petters. S. W. 1982. Central West African Cretaceous-Tertiary benthic foraminifera and stratigraphy. Palaeontographica Abt. A 179, 1-104.
Petters, S. W. and Ekweozor, C. M. 1982. Petroleum geology of the Benue trough and southeastern Chad basin, Nigeria. AAPG Bulletin 66, 1141-1149.
Petters, S. W. 1986. Foraminiferal biofacies in the Nigerian rift and continental margin deltas. In: Oti, M. N. and Postma, G. (Eds), Geology of Deltas. AA Balkema, Rotterdam, pp219-235.
Pettijohn, F.J. 1957. Sedimentary Rocks. Harper Bros, New York, N.Y., 2nd edition, 718pp.
Rahaman, M. A. 1976. Review of the basement geology of southwestern Nigeria. In: Kogbe, C.A. (Ed.), Geology of Nigeria, 2nd edition, Elizabethan Publishers, Lagos, pp41-58.
Rahaman, M. A. and Ocan, O. 1978. On relationships in the Precambrian migmatic gneisses of Nigeria. Nigerian Journal of Mining and Geology 15, 23-32.
Rahaman, M. A. 1981. Recent advances in the study of the basement complex of Nigeria. Abstract, 1st Symposium on the Precambrian Geology of Nigeria.

Rahaman, M. A., Emofurieta, W. O. and Caen-Vachette, M. 1983. The potassic-granites of the Igbeti area: further evidence of the polycyclic evolution of the Pan-African belt in south-western Nigeria. Precarnbrian Research 22, 75-92.

Rahaman, M. A. and Lancelot, J. R. 1984. Continental crust evolution in SW Nigeria: constraints from U/Pb dating of pre-Pan-African gneisses. In: Rapport d'activite 1980-1984 – Documents et Travaux du Centre Geologique et Geophysique de Montpellier 4, pp41.

Rahaman, M. A., Van Breeman, O., Bowden, P. and Bennett, J. N. 1984. Age migration of anorogenic ring complexes in Northern Nigeria. Journal of Geology 92,173-184.

Rahaman, M. A. 1988. Recent Advances in the Study of the Basement Complex of Nigeria. In: Geological Survey of Nigeria (Ed), Precambrian Geology of Nigeria, pp11-43.

Reijers, T. J. A., Nwajide, C. S. and Adesida, A. A. 1997. Sedimentology and Lithostratigraphy of the Niger Delta. Abstract, 15th International Conference of the Nigerian Association of Petroleum Explorationist (NAPE), Lagos, Nigeria.

Reijers, T. J. A. and Nwajide, C. S. 1998. Geology of the Southern Anambra Basin. Unpublished Report for Chevron Nigeria Limited. Field Course Note 66pp.

Reyment, R. A. 1965. Aspects of the Geology of Nigeria. Ibadan University Press, 133pp.

Reyment, R. A. 1966. Studies on Nigerian Upper Cretaceous and Lower Tertiary Ostracoda: stratigraphical, aaleoecological and biometrical conclusions. Stockholm Contributions in Geology 14, 1-151.

Reyment, R. A. 1980. Biogeograpy of the Saharan Cretaceous and Paleocene epicontinental transgressions. Cretaceous Research 1, 299-327.

Russ, W. 1957. The Geology of parts of Niger, Zaria and Sokoto Provinces. Geolgical Survey of Nigeria Bulletin 27, 1-42.

Schull, T. J. 1988. Rift basins of interior Sudan: Petroleum exploration and discovery. AAPG Bulletin 72, 1128-1142.

Shibayan, Y. 1985. Investigation of possible chromite bearing serpentinites and associated rocks of NW Nigeria. Unpublished M.Sc. Thesis. Ahmadu Bello University, Zaria, Nigeria.

Short, K. C. and Stauble, J. 1967. Outline geology of the Niger delta. AAPG Bulletin 5: 761-779.

Stacher, P. 1995. Present understanding of the Niger Delta hydrocarbon habitat. In: Oti, M. N. and Postma, G. (Eds), Geology of Deltas. AA Balkema, Rotterdam, pp257-267.

Tijani, M. N., Loehnert, E. P. and Uma, K. O. 1997. Origin of saline groundwaters in the Ogoja area, Lower Benue Trough, Nigeria. Journal of African Earth Sciences 23, 237-252.

Tijani, M. N., and Loehnert, E. P. 2004. Exploitation and traditional processing techniques of brine salt in parts of the Benue Trough, Nigeria. International Journal of Mineral Processing 74, 157-167.

Truswell, J. F. and Cope, R. N. 1963. The Geology of Parts of Niger and Zaria Provinces, Northern Nigeria. Geological Suvey of Nigeria Bulletin 29.

Tubosun, I. A. 1983. Geochronologie U/Pb du Socle Precambrian du Nigeria. Unpublished 3 eme Cycle Thesis, Univ. des Sciences et Techniques du Languedoc. Montpellier.

Tubosun, I. A., Lancelot, J. R., Rahaman, M. A. and Ocan, O. 1984. U-Pb Pan-African ages of two charnockite-granite associations from south-western Nigeria. Contributions to Mineralogy and Petrology 88, 188-195.

Turner, D. C. 1983. Upper Proterozoic schist belts in the Nigerian sector of the Pan-African Province of West Africa. Precambrian Research 21, 55-79.

Udensi, E. E., Osazuwa, I. B. 2004. Spectral determination of depths to magnetic rocks under the Nupe Basin, Nigeria. Nigerian Association of Petroleum Explorationists (NAPE) Bulletin 17, 22–27.

Umunnakwe, P. U. 1985. Developing a new mine - the Itakpe case. 21st Annual Conference of the Nigerian Mining and Geosciences Society, Jos. Mimeographed paper 17.

Urvoy, Y. 1936. Structure et modele du Soudan Francaise (Colonie du Niger). Ann. de Geographie 253, 1-19.

Van Breemen, O., Pidgeon, R. T. and Bowden, P. 1977. Age and isotopic studies of some Pan-African granites from north central Nigeria. Precambrian Research 4, 317-319.

Weber, K. J. 1972. Sedimentological aspects of oil fields in the Niger Delta. Geologe en Mijnbouw 50, 559-576.

Weber, K. J. and Daukoru, E. 1975. Petroleum Geology of the Niger Delta. In: Proceedings, 9th World Petroleum Congress. Applied Science Publishers, London 9, 209-221.

Weber, K. J. 1986. Hydrocarbon distribution patterns in Nigerian growth fault structures controlled by structural style and stratigraphy. AAPG Bulletin 70, 661-662.

Whiteman, A. 1982. Nigeria: Its Petroleum Geology, Resources and Potential. Graham and Trotman, London, 381pp.

Woakes, M. and Bafor, B. E. 1983. Primary gold mineralization in Nigeria. In: GOLD '82: In: Foster, R. P. (Ed), The Geology, Geochemistry and Genesis of Gold Deposits. Geological Society of Zimbabwe, Special Publication No. 1. Balkema, Rotterdam.

Woakes, M., Rahaman, M, A. and Ajibade, A. C. 1987. Some metallogenetic features of the Nigerian basement. Journal of African Earth Sciences 6, 54-64.

Wright, J. B. 1970. Controls of mineralization in the Older and Younger tin fields of Nigeria. Economic Geology 65, 945-951.

Wright, J. B. and McCurry, P. 1970. First occurrence of Manganese ores in Northern Nigeria. Economic Geology 65,103-106.

Wright, J. B. 1985. Geology and Minerla Resources of West Africa. George Allen & Unwin, London, 187pp.

Zanguina, M., Bruneton A. and Gonnard, R. 1998. An introduction to the petroleum geology of Niger. Journal of Petroleum Geology 21, 83-103.