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PUBLIC LECTURE

On

SOURCE ROCKS AND SORCERERS: DECODING THE ORIGIN OF THE NIGER DELTA PETROLEUM

By

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DEDICATION

For my girls,

Ogechi “Baby” Nefertiti
&
Akunna “Kiki” Kenyatta

WHO SAID, “THE BEAUTIFUL ONES ARE NOT YET BORN?”

PROLOGUE

Inorganic Vs Organic Theory of Origin of Petroleum.

Against the present day credo of the organic origin of petroleum, it may be difficult to believe that in the early days of the oil industry, the abiogenic (inorganic) origin of petroleum held sway. In 1877, Russian Scientist Mendeleev (of the Periodic Table fame) proposed that metal carbides deep within the earth reacted with water at high temperatures to form acetylene which subsequently condensed to form heavier hydrocarbons (as is readily demonstrated in the lab). $CaC_2 + 2H_2O = C_2H_2 + Ca(OH)_2$

In 1890, Sokoloff propounded that `bitumina', originated from meteorites and that this petroleum was extruded from the earth's interior into the surface sediments. They were the first Sorcerers. Others (eg. Vernadsky, Kudryavtsev) were to follow with differing concepts of the Inorganic Origin of petroleum including Volcanic Origin Theory, Earthquake Outgassing, etc. Their views received great support from their peers (and still linger in some quarters!). Then came the period in the early 1900s when advances in the knowledge of the composition of petroleum saw the ascendancy of the Theory of Organic Origin. In particular, the discovery of the optical activity of petroleum (Walden, 1906) and of the presence of chlorophyll porphyrins (Treibs, 1934) confirmed the low temperature origin and history of petroleum and thus cemented the Organic Theory. Subsequently, the search for petroleum moved to the great sedimentary basins of the world. The successes scored seemed to put paid to the inorganic Theory. The organic Sorcerers seemed to have won. Or did they? In the 1990s, a new set of Sorcerers led by T. Gold reignited the Inorganic Theory. Largely supported by the state-owned Swedish electricity utility Vattenfall, he caused a deep well (6.5 km by 1997) to be drilled into the crystalline basement rocks in Sweden in search of predicted petroleum of inorganic origin but the outcome was a dry hole. Was that the end of the Inorganic Theory? Perhaps, not.

In the last few years, Prof Samar Abbas of the Department of Physics, Utkal University. Bhubaneswar, India, has resuscitated the Inorganic Theory in a new proposition that calls for a Duplex theory of Origin of Petroleum, i.e. admitting both the Inorganic and Organic Theories. Claiming that, " new results from deep holes all across the world are difficult to describe in terms of the biological theory" Prof Abbas posited that, " recent advances in interdisciplinary fields as diverse as astrophysics, cosmo-geophysics, thermodynamics, nuclear geology, etc. have led to interesting developments in the non-organic theory of the genesis of petroleum"(Abbas, 2012).Because I suspect that we have not heard the last from the proponents of the Inorganic Theory, I wish to state unequivocally that this Paper is anchored squarely on the Organic Theory of the Origin of Petroleum. No prevarications!

Protocol:

Preamble (Being born Protestant):

I count it a special privilege and a distinct honour to have been invited by this celebrated Academy to give this Public Lecture at this unique location.

I join the President of the Academy in thanking our Chief host, the Vice Chancellor of FUPRE, Professor Ahoemene Akii Ibhadode. It is clear from the evidence out there that this Professor of Production Engineering has turned FUPRE into a production hub of men and materials (including a mini Refinery due to commence test production end 2016) since he arrived here in mid-2015.Talk about hitting the ground running!

I would like to acknowledge the clairvoyance of Emeritus Professor David Okali who invited me to join the Academy following my partial return to Nigeria from the Diaspora. He had said to me that I had no business outside of the Academy. I did not ask Why? I can only surmise that the Doyen knew, in the words of Andrew Loyd-Weber's Evita that, **"I will be good for you."** Mother Mary, Help Me!

Presently, I wear the hat of the University of Port Harcourt where for the last three years, I have served as a distinguished Visiting Scholar from the Diaspora, first at the invitation of **A Man For All Seasons, Eminent Professor Joseph Atubokiki Ajienka** FA Eng and, in the last year, with the indulgence of the current VC, the **irrepressible Professor Ndowa E. S. Lale** FAvH. I want them to know how much I cherish the time that I have spent with them at UNIPORT and their recognition of the difference that our collaboration has made to the University space and orientation.

I would be remiss if I forget to mention my "Home University," the University of Calabar and in particular its Institute of Oceanography where I was a founding Visiting Lecturer in the early 1980s. I have since crisscrossed the world mostly in the service of the United Nations System, taught as guest lecturer in faraway lands as India, China and Ukraine but there has always been a welcoming berth for me each time "this prodigal" returned. Understandably, it was to be my first stop when the National Universities Commission appointed me a Distinguished Scholar in Diaspora in 2011. Each time I reminisce about my love affair with UNICAL, the song of the American crooner of the 1960's, Neil Sedakar, comes to mind: **"Breaking up is hard to do!"**

First, a few quick definitions to set the stage:

Source Rocks: Exploitable trapped petroleum accumulations require the presence of effective petroleum source rocks. Also called "mother rocks", it is in these rocks that petroleum hydrocarbons are generated. Source rocks are the most essential requirement for an oil-bearing area. This more commonplace term is used here to go along with the majority of geologists and geochemists who prefer it. For the purist, however, the term "source bed" is more appropriate in most situations as a more inclusive term covering both source sediment and source rock.

Sorcerers: This is my pet term for all those, past and present, preoccupied with the identification of source rocks. The history of the petroleum industry is strewn with the "escapades" of these "high priests" that span all shades of adherents from inorganic to organic theorists and from foot soldiers of the anticlinal theory of petroleum occurrence(1880s) to enthusiasts of the concept of petroleum systems(1980s).

DIVERSIFICATION- DIVERSIFY WHAT?

Mr President, the current clamour for the diversification of the Nigerian Economy from an oil centered enterprise to one that is multipronged is an old cry dating back to the mid-1970s when Nigeria first came to prominence on the world stage as a major oil producer.

The paradox is the inaction that has left the nation with unfulfilled dreams in this regard. It would take more than this lecture to x-ray the reasons for this seeming impotence. Briefly, my submission is that we have allowed ourselves as a Nation to be cajoled into a loss of collective self-confidence by motley of national con artists and foreign sophists. We have become a country of "talkers" not "doers." Those who should have made a difference either have self-effacingly abandoned the public space or have been unwittingly marginalized; charlatanry threatens the land.

I digress; I must move on to the business of the day!

I wish to submit, up front, that much as it is well intentioned, the piercing calls for diversification in the Economy away from petroleum should, in fact, start with a focus on diversification within the oil industry. Our ambitions to join the club of the 20 most advanced economies in the world by the year 2020 may well hinge on it; well, among other things!

Is it a contradiction to call for the intensification of exploration for more petroleum reserves in the midst of the cacophony of voices for diversification of the economy away from petroleum?

No!

Petroleum underpins our present industrial civilization. It is the source of our chemicals; it provides fuel for our automobiles, engines, airplanes, ships; supplies energy for our power stations; and feed stock for a variety of manufacturing activities. That is not all! One only needs to look at **Table 1**to know how our everyday living is hinged on petroleum. I do not mean to be irreverent but it would appear that the understanding of Petroleum is the beginning of wisdom!

Hence the various predictions of a penury of supplies of petroleum threaten global lifestyle; maybe our very civilization! It is, therefore, not surprising that even in the face of the slump in oil prices, countries are still prospecting for petroleum at a frenetic pace at home and abroad and locking their finds into their known reserves. More than ever before, many more corporations globally are jockeying for oil exploration licenses in new territories particularly in the deep offshore ocean. Egbogah & Lambert –Aikhionbare (1979; 1980) had scoped new frontiers for exploration. Beka and Oti (1995) noted the tremendous interest in exploration of the distal offshore Niger Delta "---as witnessed by the recent acquisition of new production acreages in the deep offshore by the major oil companies---

." These Oil Companies must know something. In truth, they do! The oil gusher that Shell's deep offshore concession, Bonga Field, proved to be would cement this viewpoint.

Nigeria must not comport itself differently. And must pay attention to this global trend.

For a country of 170 million people, with a crippling dearth of infrastructure and a suffocating absence of amenities and essential services, a 2.4 million bbls of daily crude oil production is not a big deal. A rational diversification scheme in the petroleum industry predicated on the optimal internal utilization of our crude oil production (in refining, petrochemicals, and as feed stock in manufacturing), would easily gobble up current production limits. There will be little or nothing left for export!

The need is urgent to create buffers in our petroleum production. It implies a pressure to increase national petroleum reserves which, in its turn, calls for an intensification of exploration efforts.

Why this focus on the Origin of the Niger Delta Petroleum?

An old saying in the Oil Industry holds that:

"IF YOU KNOW HOW IT ORIGINATES, YOU KNOW WHERE TO FIND IT".

This underscores the significance of today's lecture

On this subject, Fuloria (1967) wrote in the Bulletin of the American Association of Petroleum Geologists:

"If oil and gas are of great importance to a particular country, a proper knowledge of the source of these mineral fuels is of still greater importance to a petroleum geologist, because without this knowledge he cannot guide exploration activities for oil and gas with the maximum effectiveness required by a proper exploration program"

***Table 1. Why Do We Need Petroleum: Products Made from Oil?

Ink	Dishwashing liquids	Paint brushes	Telephones
Toys	Unbreakable dishes	Insecticides	Antiseptics
Dolls	Car sound insulation	Fishing lures	Deodorant
Tires	Motorcycle helmets	Linoleum	Sweaters
Tents	Refrigerator linings	Paint rollers	Floor wax
Shoes	Electrician's tape	Plastic wood	Model cars
Glue	Roller-skate wheels	Trash bags	Soap dishes
Skis	Permanent press clothes	Hand lotion	Clothesline
Dyes	Soft contact lenses	Shampoo	Panty hose
Cameras	Food preservatives	Fishing rods	Oil filters
Combs	Transparent tape	Anesthetics	Upholstery
Dice	Disposable diapers	TV cabinets	Cassettes
Mops	Sports car bodies	Salad bowls	House paint
Purses	Electric blankets	Awnings	Ammonia
Dresses	Car battery cases	Safety glass	Hair curlers
Pajamas	Synthetic rubber	VCR tapes	Eyeglasses
Pillows	Vitamin capsules	Movie film	Ice chests

Candles	Rubbing alcohol	Loudspeakers	Ice buckets
Boats	Ice cube trays	Credit cards	Fertilizers
Crayons	Insect repellent	Water pipes	Toilet seats
Caulking	Roofing shingles	Fishing boots	Life jackets
Balloons	Shower curtains	Garden hose	Golf balls
Curtains	Plywood adhesive	Umbrellas	Detergents
Milk jugs	Beach umbrellas	Rubber cement	Sun glasses
Putty	Faucet washers	Cold cream	Bandages
Tool racks	Antihistamines	Hair coloring	Nail polish
Slacks	Drinking cups	Guitar strings	False teeth
Yarn	Petroleum jelly	Toothpaste	Golf bags
Roofing	Tennis rackets	Toothbrushes	Perfume
Luggage	Wire insulation	Folding doors	Shoe polish
Fan belts	Ballpoint pens	Shower doors	Cortisone
Carpeting	Artificial turf	Heart valves	LP records
Lipstick	Artificial limbs	Hearing aids	Vaporizers
Aspirin	Shaving cream	Wading pools	Parachutes

***This list of products made from petroleum is modified by David & Sheila Kopaska-Merkel of Geological Survey of Alabama and Brian Neil of Shell Offshore Inc. of Loiuisiana from the American Petroleum Institute's (API) "Petrochemical Products" list and from Laurie Sachtleben's article "Products from Petroleum" (Chevron World magazine, Winter, 1999)

So, it has everything to do with **"Source rocks"**that generate thepetroleum and the **"Sorcerers"** that locate them!

The application of the knowledge of the origin of petroleum and, in particular, its deployment within the concept of petroleum systems now actively promoted by geochemists, can improve the nation's domestic resource base in a shorter time and at a more reasonable cost than would have been possible otherwise. Under the concept, Geochemists develop input into basin modelling which provides quantitative integrated models, including source, migration, reservoir, seal and trapping mechanisms. It is a "Big Picture" approach to petroleum exploration in which the totality of factors favouring petroleum accumulation are in play **(Table 2).**

Properly interpreted, information from source rock studies can save corporations (and countries) millions of dollars in unnecessary exploration and development efforts while at the same time providing geologic clues to the discovery of tremendous reserves.

THE ACCIDENTAL GEOCHEMIST

A book published in the course of the last two years or so is entitled "The Accidental Public Servant." A variation of this title, to wit, "The Accidental Geochemist" would have been an apt title for my lecture.

Having transited from Geologist to Petroleum Engineer in the service of Shell-BP Petroleum Development (Nig) Company Ltd and elected to membership of the Society of Petroleum Engineers(SPE) of the American Institution of Mining Engineers(AIME) in late 1977, I was about to set out for the Royal School of Mines, Imperial College of Science and Technology, London to undertake graduate studies on the "Mobility of Cations in Fine Grained Sediments in the Wash Estuary, United Kingdom"

The research was destined to contribute knowledge to the resolution of a nagging engineering problem in oil field production in the Niger Delta and other rapidly formed depositional environments. Due to the friable (highly unconsolidated) nature of the petroleum reservoir rocks, there is high incidence of mobility of "fines" (sand, actually) which frequently clog the perforations in the production stem necessitating costly "Workover" jobs. I was to focus on two key processes – the loss of mechanical integrity as the rock fails and the disintegration of the failed rock because of hydrodynamic forces.

Table 2. Essential Requirements for Favorable Petroleum Prospects.

1.	A sufficient source of the proper organic matter
2.	Conditions favorable for the preservation of the organic matter—rapid burial or a reducing environment
3.	An adequate blanket of sediments to produce the necessary temperatures for the conversion of the organic matter to fluid petroleum
4.	Favorable conditions for the movement of the petroleum from the source rocks and the migration to porous and permeable reservoir rocks
5.	Presence of accumulation traps, either structural or stratigraphic
6.	Adequate cap rocks to prevent loss of petroleum fluids
7.	Proper timing in the development of these essentials for accumulation and a post accumulation history favorable for preservation

***Source*:** From Hedberg, H. D., J. D. Moody, and R. M. Hedberg (1979). Petroleum prospects of the deep offshore. American Association of Petroleum Geologists Bulletin 63, 286–300, p. 288.

In conversations with my Petroleum Engineering Manager, Engr Kum Weber (of the Weber and Daukoru fame!), he agreed it was an enterprise that would save not only frustrations but the annual huge costs of sand exclusion operation seven if he feared that my exit to London would mean a loss of one of his dependable and upwardly mobile staff.

I was late in setting out to Imperial College because of a delay in the announcement of an expected scholarship from the newly established Petroleum Technology Development Fund (PTDF) of the Nigerian National Oil Company (NNOC, later, NNPC). I notified the Royal School of Mines. An Air Mail arrived asking if I would consider an even more pressing problem in the petroleum industry at large.

The alternative project turned out to be the enigma of the source of the petroleum found in prolific carbonate basins which hold more than 50 percent of the world's conventional petroleum reserves but which do not conform to the conventional wisdom that shales are exclusively source rocks while sandstones and carbonates are reservoir rocks. The bias led geologists to strive to identify shale source beds even though such shales may be far removed from the carbonate reservoirs in time and space.

Typical examples are the Arab zone oil fields of Saudi Arabia, among the world's largest producers of oil, in which the 400ft thick porous productive Arab zones of Jurassic age are

surrounded by sealing beds of either anhydrite or dense limestone **(Fig 1**) in a nearly closed system.

So, no obvious shale formations in the region; no long fracture zones that would have brought the oil from faraway lands even if some shales existed; nothing, just carbonates everywhere. How did the oil get in there? An enigma, indeed, begging for resolution and British Petroleum (BP) among other International 0il Companies had approached Imperial College, London, to help unravel the enigma.

I finally arrived London at the end of December,1977. Early in 1978, I was offered a proposal to enquire into "The Origin of Petroleum in Carbonate Rocks" within the fledgling field of Organic Geochemistry. I was told that there would be travels to the Persian Gulf, the USA and the Bahamas for field work in modern carbonate environments. It was irresistible! Travelling had always fascinated me! I said, YES. And that began my "journey into the great unknown." It was reckless; well, almost!

To cut a long story short, after barely two years of painstaking research, I unveiled the enigma in late 1979 by **providing geochemical evidence that carbonate rocks, including those of sand size consistency, are syngenetically oil bearing (see fig 2).**

No more the need for a recourse to convoluted theories about possible shale source rocks in far flung places or some nebulous explanations of long range migration that defied common sense. My Ph. D Thesis was accepted in 1980 as a Publication of the University of London.

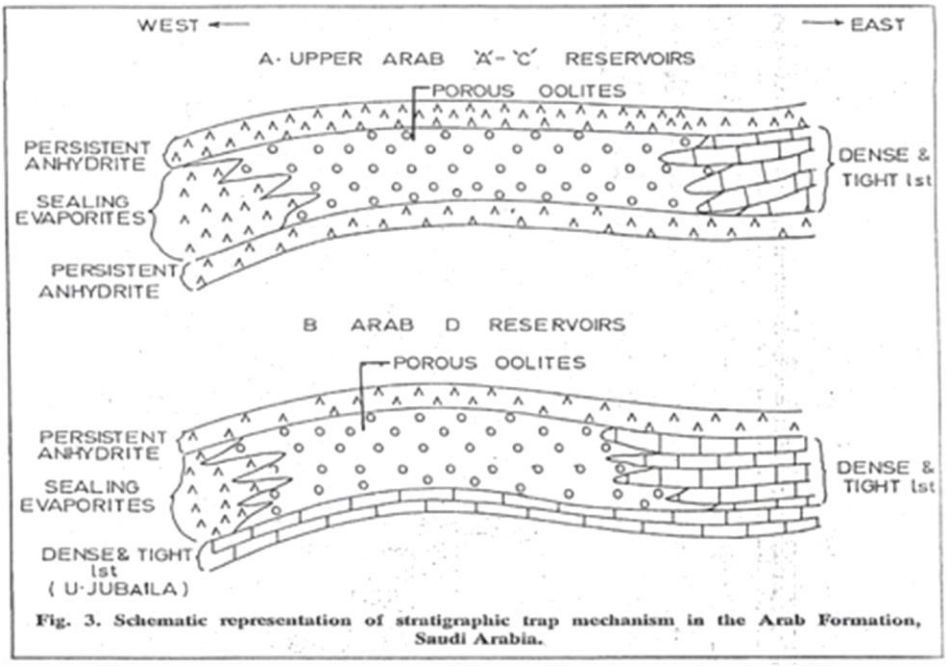


Fig. 1: Schematic representation of stratigraphic trap mechanism in the Arab Formation. Saudi Arabia. (Ibe, 1985).

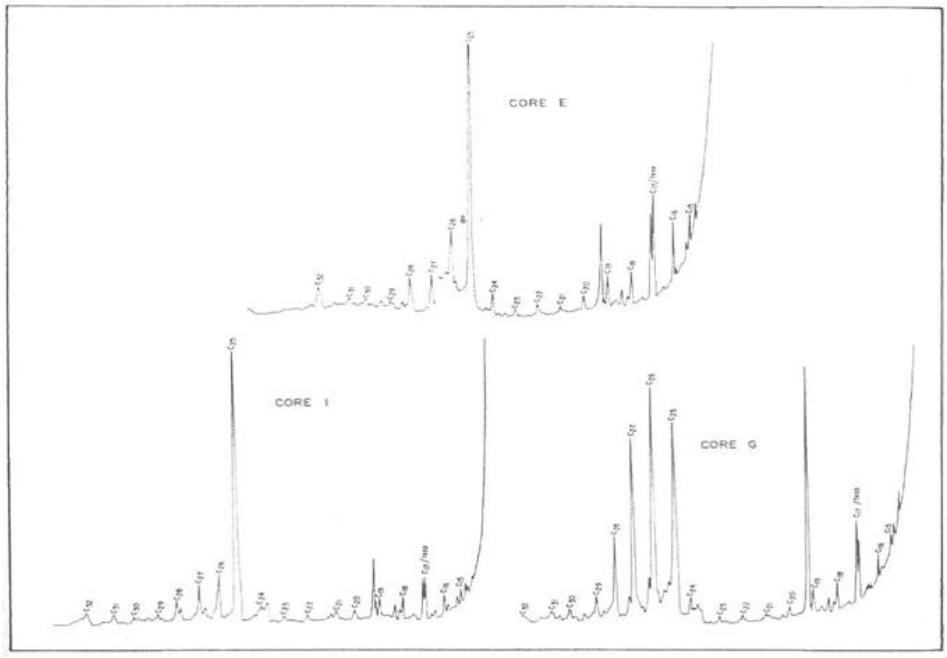


Fig. 2: Gas chromatograms of analysis of bitumen "whole extracts" revealing the n-alkane (numbered) composition of Recent oolites. (From Ferguson and Ibe, 1982.

Writing in the Journal of Petroleum Geology, Ferguson and Ibe (1981) noted;

"The excellent porosity and permeability characteristics of oolitic carbonates have been used to explain the notably superior production of hydrocarbons when compared with most other reservoir rocks. However, we have found that Recent ooid sands contain light hydrocarbons which we believe to be authiginic. The significance of these hydrocarbons is not in the fact of their occurrence, but in the ratio of methane to the other hydrocarbons present. (ethane, propane, etc.). **TO OUR KNOWLEDGE, NO SIMILAR DISCOVERY HAS BEEN REPORTED.** This Paper seeks to account for the formation of these hydrocarbons, and to relate the process to an overall scheme of petroleum genesis. In addition to providing a new insight into the timing, depth and nature of light hydrocarbon generation, the results present the possibility of the role of oolites as source rocks.".

The High and Mighty in the Petroleum Geology and Engineering world cried, "HERESY!" They said carbonate sediments and rocks are decidedly organic matter poor; what will generate the hydrocarbons? However, our findings stood the test including many successful replications of our experiments by different Laboratories in the USA and Europe. Previous extraction techniques tended to decimate the organic matter. Why did researchers not pause to ask, "what happens to all the organic matter we see in recent carbonate environments?"

Our discovery that carbonate rocks are syngenetically oil bearing was to revolutionize the thinking on the Origin of Petroleum in Carbonate Rocks (Ibe, 1980; Ferguson and Ibe, 1981, 1982; Ibe, 1982, 1983, 1984, 1985; Ibe et al, 1983)

The world heaved a sigh of relief as the heresy of the day before became the conventional wisdom of the day after.

A NEW STAR WAS BORN!

I HAD BECOME AN ACCIDENTAL GEOCHEMIST!

NIGER DELTA, HERE I COME!

In Shakespeare's "Macbeth," Duncan who was aspiring to be King, in resisting the entreaties of his wife to murder the visiting King Macbeth in his sleep so that he would become king as the witches had predicted had insisted, "If chance would have me king, why, chance would crown me".

For me, that "chance" was the good fortune to meet and to have as contemporaries at Imperial College, London, two Nigerians - Dan Lambert (De lamb)- Aikhionbare who was working on the diagenesis of the sandstone reservoirs in relation to petroleum occurrence in the Niger Delta and Francis (Layi) Fatona who was unveiling the sedimentology and stratigraphy of fossil fuel deposits in England's Nottinghamshire district. We all had Oil Company backgrounds. During the many weekend gatherings over meals of English steak and kidney pies washed down with hurriedly prepared Nigerian pepper soup, we spent much time musing over the Origin of the Niger Delta Petroleum.

First, there was the postulation that the shales in the paralic Agbada "Formation" were the source of the hydrocarbons that occur in the contiguous reservoirs of the "Formation" (Short and Stauble, 1967; Frankl and Cordry, 1967, Reed, 1969). Then came an alternative proposal identifying the deeper open marine shales of the Akata "Formation" as the major source rocks (Weber and Daukoru, 1975, Evamy, et al, 1978). We thought one of the alternative viewpoints had to be right; but on what evidence? Why not apply similar geochemical techniques that clarified the carbonate question?

De Lamb had for his studies abundant borehole samples from a wide scattering of Oil Fields in the Niger Delta including from the Akata "Formation" which had always been difficult to sample; only a few wells had penetrated it on account of worries linked to its over-pressured nature. So, we went to work!

GEOLOGIC SETTING AND LITHOSTRATIGRAPHY OF THE NIGER DELTA

The evolution of the Niger Delta **(Figs 3 &4)** is controlled by pre- and syn-sedimentary tectonics as described by Short & Stauble (1967); Frankl and Cordry (1967); Weber and Daukoru (1975); Evamy et al. (1978); Ejedawe (1981); Knox & Omatsola (1987); Doust and Omatsola(1990); Stacher (1995);Corredor et al (2005), among others.

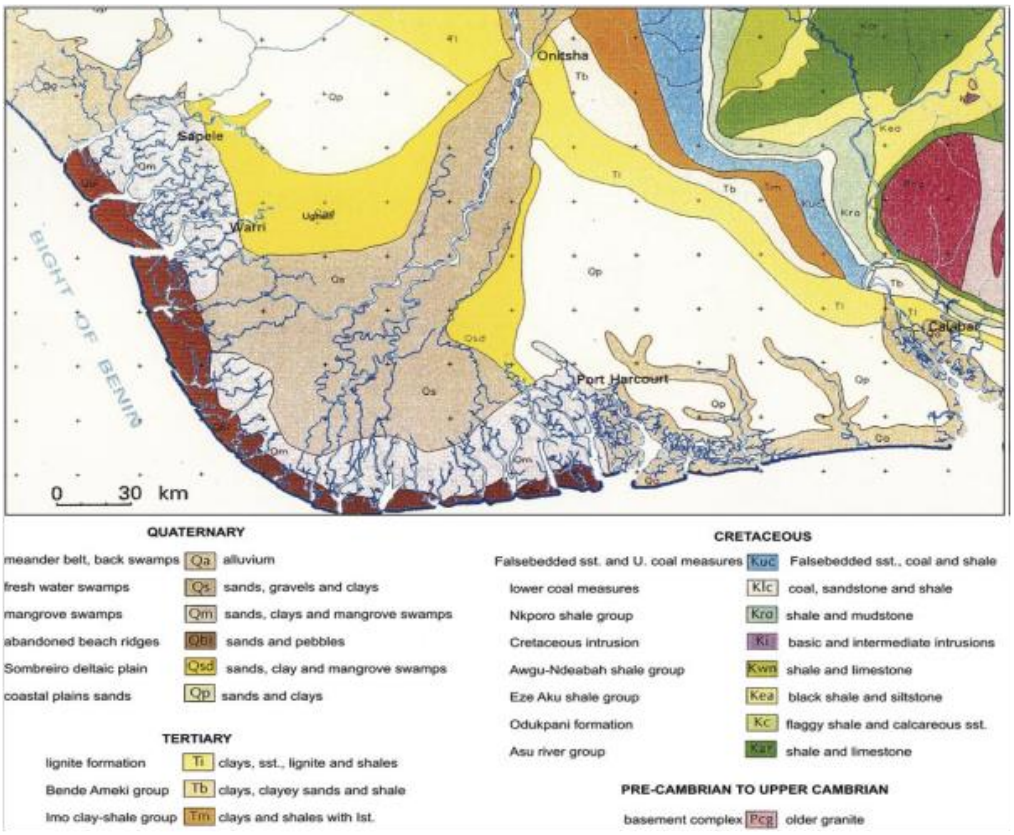


Fig. 3. Geological map of the Niger Delta and surroundings (from Reijers, 2011).

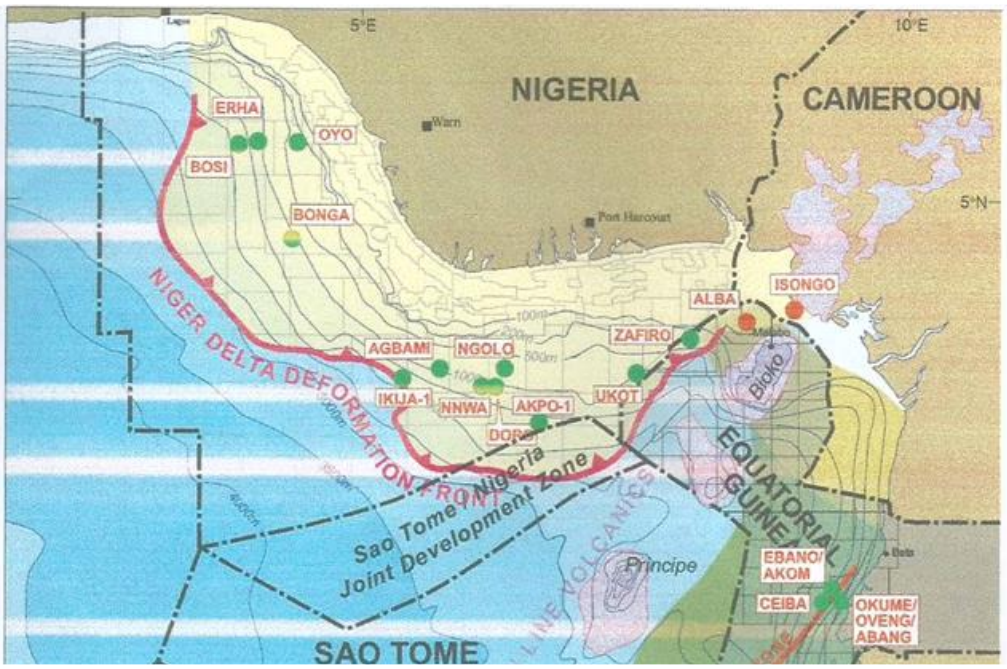


Fig. 4: Map of Niger Delta, showing the Offshore Oil Fieldsfrom Klett et al (1997)
Other factors that controlled the growth of the delta were climatic variations and the proximity and nature of sediment source areas (Allen, 1955,1964; Short & Stauble, 1967; Reed,1969; Ibe,1982,1985, 1988a, b, c; 1990, 1994; Ibe and Awosika, 1986; Reijers et al, 1997; Reijers, 2011)

For the interested reader, a handful of publications that describe present day oceanographic conditions along the Western African coast in general and in offshore Nigeria in particular have been added to the List of References. (Chuku and Ibe,2015; Ibe, 1983; Ibe,1984; Ibe,1986; Ibe,1987; Ibe,1988 a,b,c: Ibe,1989 a,b,c,d,e,f; Ibe and Quellenec, 1989; Ibe,1990 a,b,c; Ibe,1991, Ibe, 1992a,b; Ibe,1993 a,b,c,d; Ibe and Ojo, 1994; Ibe, 1995; Ibe, 1998a,b;Ibe and Abe 2003;Ibe,2006; Ibe, 2013, 2015; Onuoha, 1981a). On the basis of **"the present as a key to the past," (The Concept of Uniformitarianism),** they provide some insight into the past processes of relevance to this Paper.

The lithostratigraphy of the Niger Delta is a direct product of the depositional controls mentioned above. Short and Stauble (1967), identified the three "Formations" corresponding to these environments from well sections: an upper delta top lithofacies, the Benin Formation(up to 2000 m thick; Oligocene to Recent), consisting of massive continental sands and gravel, and is underlain gradually by the delta front paralic lithofacies, the Agbada "Formation"(more than 3500 m; Eocene to Recent), comprising mostly sands with minor shales in the upper part and an alternation of sands and shales in equal proportions in the lower part. Prodelta marine shales belonging to the Akata "Formation" (with thickness from 2000m at the most distal part of the delta to 7000m; Paleocene to Recent) occur lower in the section. The Niger Delta lithostratigraphic units are strongly diachronous. The units started accumulating since deltaic progradation

commenced in the Early Tertiary (Fig 5). The Akata "Formation" is under-compacted and over-pressured (Merki, 1972, Schlumberger, 1985).

Today, the delta has been penetrated by more than 5,000 wells and is covered with a dense grid of 2-D and 3-D seismic data that clarify the subsurface formations. The improved tie of bio-zones to the radiometric time-scale have considerably improved the accuracy of detailed stratigraphic analyses. Reijers(2011), based on the work of the Inter-Agency Stratigraphic Committee on the Niger Delta, had suggested that these dominant "FORMATIONS" (according to the terminology of Short and Stauble, 1967;and Evamy et al, 1978) be given the higher designation of "GROUPS", which is the nomenclature adopted in this discussion. I will return, under the title, **"AN UNFINISHED BUSINESS,"** to justify this preference before concluding the lecture.

THE ORIGIN OF THE NIGER DELTA HYDROCARBONS.

Improved understanding afforded by regional integration of results from conventional exploration, structural analysis, and gravity-magnetic data, indicate that there are three petroleum systems in the Niger Delta and delta frame: Lower Cretaceous(lacustrine), Upper Cretaceous-Lower Paleocene (marine) and Tertiary(deltaic), (Haack, 2000).

It has to be made clear, therefore, that the focus of this discussion is the Origin of the Petroleum hydrocarbons in the Tertiary Niger Delta.

The Petroleum Geology of the Tertiary Niger Delta has been the subject of extensive reviews by Frank and Cordry (1967), Short and Stauble (1967), Weber and Daukoro(1975), Evamy et al(1978), Ekweozor and Okoye(1980), Petters, (1984), Lambert-Aikhionbare and Ibe (1980,1984). Others include Ejedawe et al (1984), Nwachukwu and Chukwura (1986), Doust and Omatshola (1990), Reijers et al (1997) and Reijers (2011).

Petroleum occurs in the sandstone reservoirs found in the paralic Agbada Group. In addition to conventional growth fault related traps, there are non- conventional stratigraphic traps related to channel fills, regional sand pinch outs and truncation (Fig 6 after Stracher, 1995).

The proposition of the Agbada shales as source (Frankl and Cordry,1967; Short and Stauble, 1967; Reed, 1969) was based on the wide.

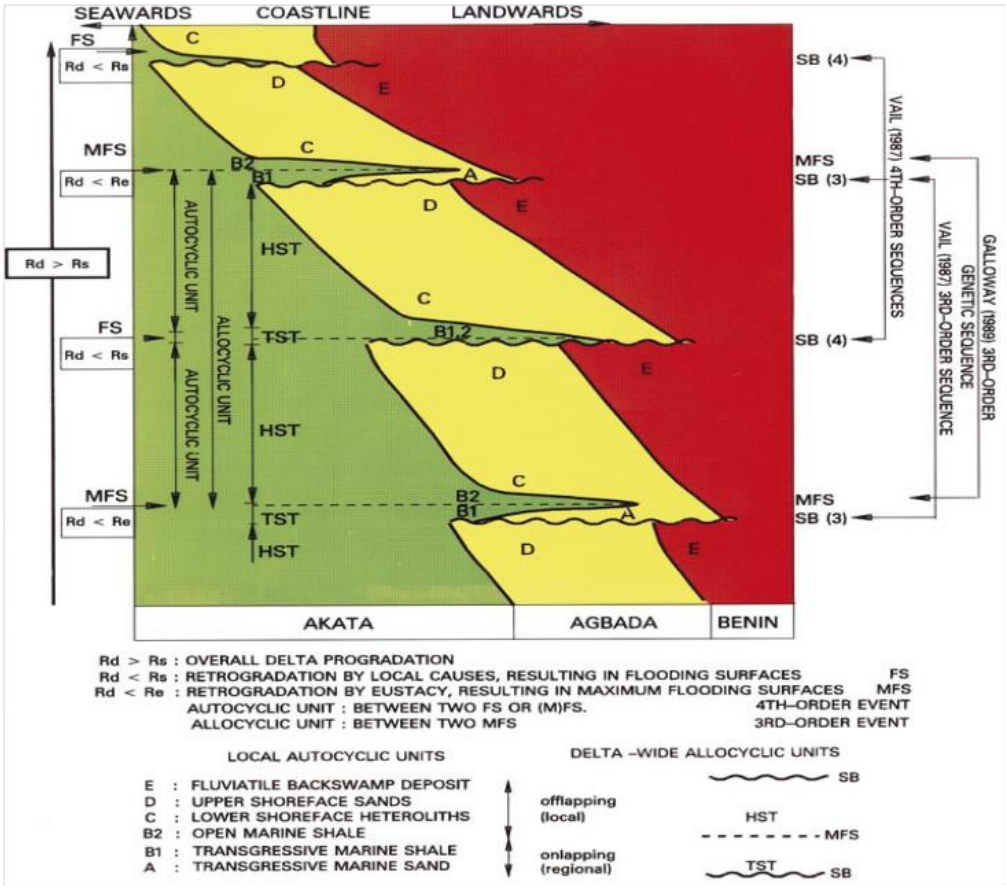


Fig. 5: Mechanisms and units of delta evolution. From Reijers(2011).

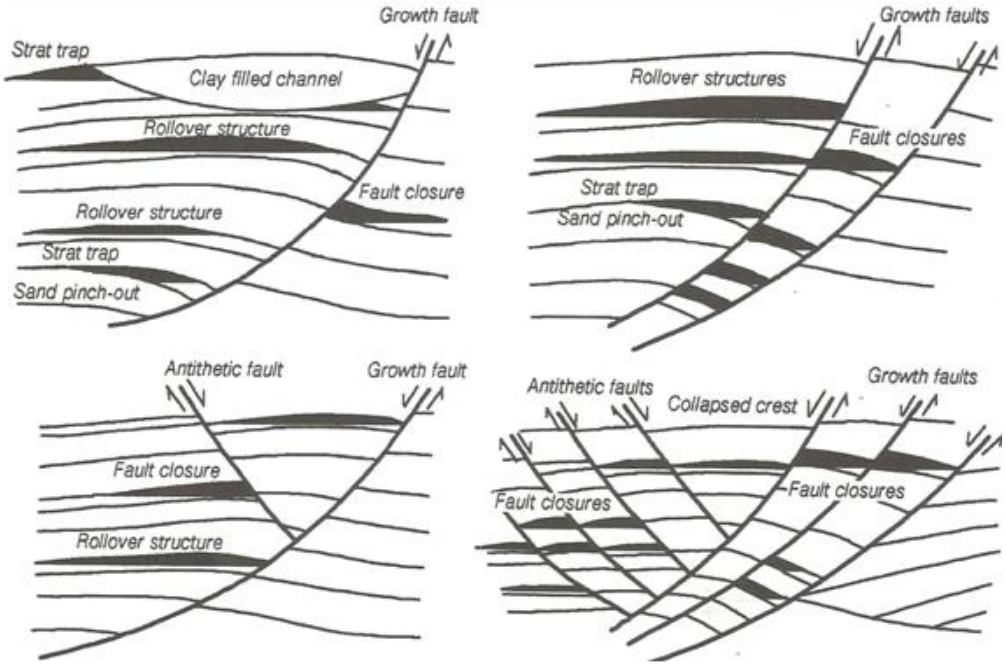


Fig. 6: Oil Field Structures and traps in the Niger Delta.

variations in hydrocarbon properties both laterally and within fields which suggested that the hydrocarbons have undergone little or no migration **(Fig 7)** and on results from foraminiferal studies. The alternative proposal of Weber and Daukoru (1975) and Evamy et al (1978) was predicated on considerations of adequate depths of burial and geothermal gradients for hydrocarbon generation and the subsequent up-dip migration via the numerous growth faults into the reservoirs. The beginnings of a controversy were sown!

Ekweozor and Okoye(1980) were the first to offer concrete organic geochemical data in support of one or the other of the two view points on the Origin of the Niger Delta Petroleum. In a Paper in the Bulletin of the American Association of Petroleum Geologiststitled, "Source- Bed Evaluation of Tertiary Niger Delta," they presented data which, "---appear to be in agreement of the views of Weber and Daukoro(1975)who first proposed that the marine source rocks of the Niger Delta were the deeply buried lower parts of the paralic sequence and the top strata of the continuous marine shales(Akata shales)."

In a Discussion of the Paper of Ekweozor and Okoye (1980) in the same Bulletin, Lambert -Aikhionbare and Ibe (1984) argued that, "our own petrographic, chemical and geologic data are, however, in variance with those of Ekweozor and Okoye(1980), and cast doubt on the validity of their conclusions." They adduced evidence to show "--- that the Agbada shales constitute the major source of hydrocarbons in the Niger Delta." Ekweozor and Daukoru (1984) wrote a Discussion of Lambert Aikhionbare and Ibe (1984) offering additional chemical evidence in support of the earlier conclusions of Ekweozor and Okoye(1980) which preferred an Akata source. A controversy was born!

Edjedawe (1986), while noting that, "regional geochemical investigation of the Tertiary Niger Delta Basin seems to be in its infancy, "claimed that, "it would appear that that differences of opinion in the interpretation of available geochemical data are related to the ambiguous use of the term source rocks in contexts which do not specify whether expulsion has occurred". It did nothing to douse the controversy.

In their wide ranging review of the opposing opinions on the Origin of the Niger Delta Petroleum, Nwachukwu and Chukwura (1986) identified "**Two Schools of Thought"** namely, the Weber and Daukoru (1975) School on the one hand and the Lambert-Aikionbare and Ibe (1984) School on the other. Another later review by the US Geological Survey (Tuttle et al, 1999) recognized this dichotomy. The Two Schools of Thought will hereinafter be referred to as the Akata School and the Agbada School.

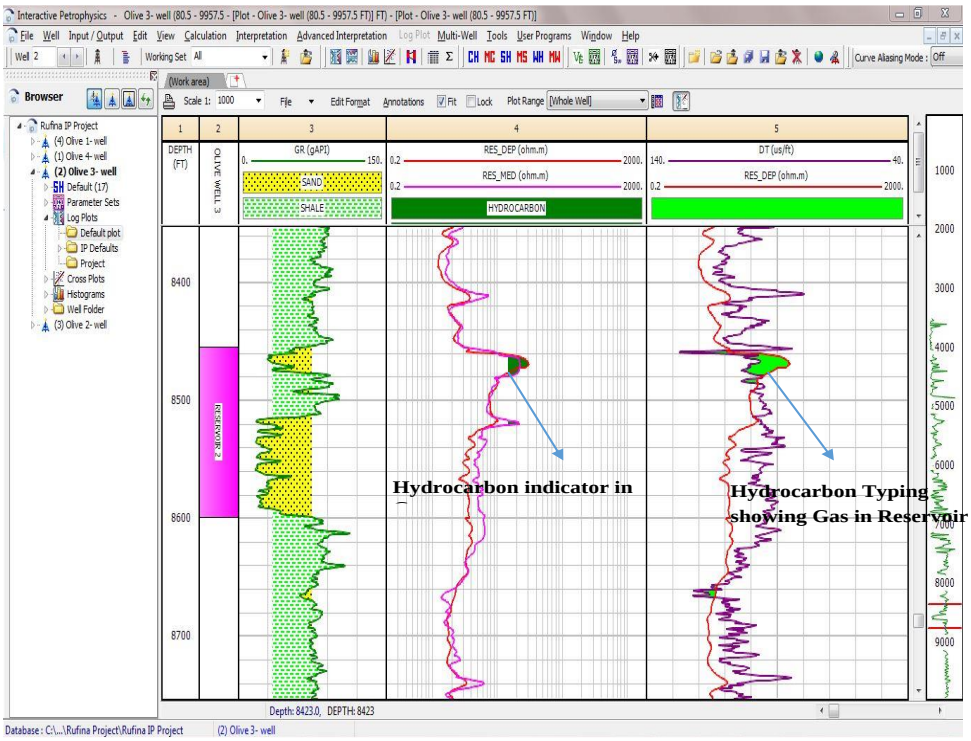


Fig. 7: Typical alternation of shales and sandstones in the Agbada Group (OLIVE FIELD: From Johnson, 2016)

This Paper revisits the controversy of the origin of the petroleum hydrocarbons in the Tertiary Niger Delta along two perspectives, (I)Geochemical Data and (II) Geological Aspects, in an attempt to clarify the debate and bring the protagonists, actual and potential, closer to the "TRUTH". For if you know how the petroleum originates, you would know where to find it!

I. GEOCHEMICAL DATA

Summarizing the views of numerous authors on source bed performance, Momper and Williams (1970) posited that four factors determine such performance during generation, and primary hydrocarbon migration, namely:

1. The Quantity of organic matter;
2. The convertibility of the organic matter to oil under the physico-chemical conditions present in the source bed;
3. The efficiency of the expulsion mechanism; and
4. The critical release range of the source bed.

The normal range of each variable necessary for an effective hydrocarbon source and the average of each variable have been determined fairly reliably from data published by some of the leading geochemists in this field. To achieve clarity while maintaining brevity, the discussions in this Section would proceed along the lines of the identified criteria.

1. **Quantity and Type of Organic Matter**

Sedimentary organic matter is extremely complex composed of many types of compounds. A minimum of organic matter must be present in a source rock to generate sufficient hydrocarbons to exceed the critical release limitation for oil expulsion. This minimum has been put at the equivalent of 0.5 % organic carbon (Hedberg et al, 1979). Momper and Williams (1970) have pointed out that source rocks containing proportionately more lignin and humic compounds require a higher critical minimum organic content of about 1.5 wt % or more.

Ekweozor and Okoye(1980)and Nwachukwu and Chukwura(1986) reported generally moderate to high TOC values of 0.4 - 4.4% and 0.2 - 6.5% respectively which agreegenerally with values of Lambert -Aikhionbare and Ibe (1984) for the Agbada and Akata shales.

The Agbada shales are paralic sequences meaning that they were formed in the fringe marine environment. PARALIC means pertaining to environments of the marine borders, such as lagoonal, littoral, shallow neritic, etc. These sites are conducive to the formation of sizable petroleum deposits because they are characterized by high rates of primary production, shallow water depths, and restricted circulation on the sea floor on which is being depositedan alternating sequence of shale and sandstones with primary hydrocarbons present in the finer sediments. As a result, they have large primary organic matter fluxes and anoxic sediments. Both favor the burial of large quantities of organic matter at rapid rates.

In this environment, the allocthonous material (mainly of terrestrial vegetal matter) arebeing brought in from the Niger- Benue fluvial system and other rivers into a sea replete with autochthonous marine organic matter (mainly of marine plankton) to form a mixed suite of organic matter (Type II).

In organic matter characterization, two parameters are of the essence; BITUMEN (soluble in organic solvent) & KEROGEN (insoluble portion). They are also referred to as “Petroleum- related” and “non- petroleum- related” components of organic matter.

1a) Bitumen is that portion of native organic matter which is soluble in ordinary organic solvents such as benzene and carbon disulphide. Ekweozor and Okoye(1980) published Bitumen extract data (see Tables 3a&b) from which they concluded that any shales in the Niger Delta shallower than 2,900m in the offshore

and 3, 375m in the onshore would not have served as source rocks. An examination of the Tables reveals that high bitumen extract values were disregarded. Ibe and Lambert -Aikhionbare (1984), using the method of Gransch and Eisma (1970) estimated the maturity of 37 shale samples obtained from the Agbada Group and 4 samples from the Akata Group spanning 11 widely scattered oil fields. Their results showed that the Agbada samples from depths as shallow as 1,800m in the flanks are thermally mature **(fig 8)** and would have served as source rocks to the contiguous sandstone reservoirs. They concluded that the high extract values found in **Tables 3a&b**were indicative of source rocks in which hydrocarbon generation had occurred, but probably after expulsion of the bulk of interstitial fluids necessary for primary migration of fluids into the nearby reservoirs (see Chapman, 1972). On the other hand, they proposed that the low bitumen extracts represent those source rocks from which hydrocarbons that had been generated had migrated (Fujita, 1977, Magara, 1980.)

1b) Kerogen is that part of sedimentary organic matter that is transformed under appropriate physico-chemical conditions into petroleum hydrocarbons. Based on microscopic examination of `pre-isolated kerogen of sample from Oroibiri 1, Ekweozor and Okoye (1980) reported that it contained approximately 64 % Vitrinites/Huminites(mainlytextinites), 7% Liptinites(dominantly sporinites and resinites) and 29%Inertites (mainly fusinites, scelerotinites and micrinites).For the other samples, the composition differed only in relative proportions from well to well and down dip. They therefore stated that the dominant kerogen type in the Niger Delta is Type III.

The kerogen data published by Lambert-Aikhionbare and Ibe (1984) revealed a dominant Type II kerogen with varying admixtures of Types I and IIIand contradicted this assertion. Data from elemental analysis (Carbon, Hydrogen, Nitrogen and Oxygen) of the Kerogens corroborated results from their petrographic examination (see **fig 9).**

Nwachukwu and Chukwwura (1986) reported that amorphous organic matter (including finely disseminated particles) constitutes 63 % of the kerogens, and terrestrial organic matter (woody remains, herbaceous materials) constitutes 30%. Recycled or coaly organic material was found to make up 7% of the kerogens. This would match the description of Type II kerogen found by Lambert Aikhionbare and Ibe (1984).

Bustin (1988), who surprisingly reported that there are no rich source rocks in the Niger Delta (average of 1.4 to 1.6% TOC in sandstone, siltstone, and shale), described mixed maceral components of amorphous organic matter (Type II) with rich admixtures of Type III. He also noted that there is no evidence of algal matter and that the shales are low in sulphur (.02 to .1 %).

Sample No.	Depth (m)	Organic Carbon (%)	Soluble Organic Matter (ppm)	Hydrocarbon Fraction (Saturated)* (ppm)	Soluble Organic Matter (mg)/Total Organic Carbon (g)	Hydrocarbon Fraction (mg)/ Total Organic Carbon (g)
46+	810	1.9	1,330	90	72	5
47+	896	2.0	1,270	120	63	6
48	953	0.5	160	5	33	1
49+	1,074	4.4	1,830	165	41	4

50	1,563	1.3	350	n.d.**	27	n.d.
51+	2,025	1.2	610	95	50	8
52	3,354	2.0	760	125	37	6
53	3,622	1.1	1,270	120	115	11

Saturated hydrocarbons only,
**** Not determined.**
+Samples with high extract values added by present writers. Table from Ekwezor and Okoye (1980)

Sample No.	Depth (m)	Organic Carbon (%)	Soluble Organic Matter (ppm)	Hydrocarbon Fraction (Saturated)* (ppm)	Soluble Organic Matter (mg)/Total Organic Carbon (g)	Hydrocarbon Fraction (mg)/ Total Organic Carbon (g)
54+	2,760	1.6	1,000	15	61	10
55+	2,830	1.7	770	10	46	5
56	2,899	1.4	300	5	21	3
57	2,960	1.5	450	20	30	15
58+	3,195	1.3	1,140	5	88	5
59	3,258	1.1	500	5	44	3
60	3,292	1.6	450	30	39	2
61	3,352	3.7	990	10	27	2
62	3,401	1.5	1,010	125	66	80
63	3,487	1.2	1,560	110	136	95

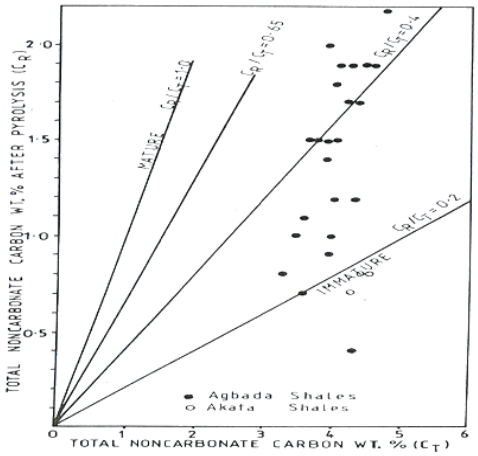


Fig. 8: 1-Plot of C_{14} (residual carbon) versus C_1 (total ca some kerogen of Agbada Agbada and Akata shales of Nig

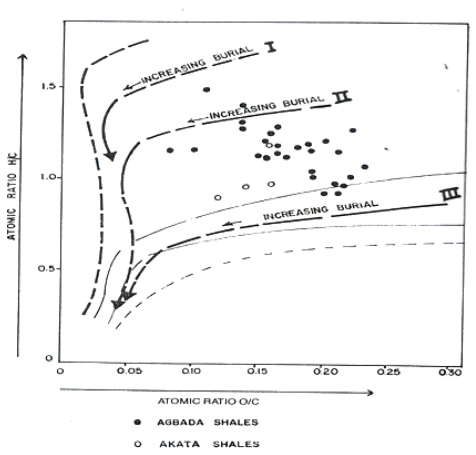


Fig. 9: Van Krevelen diagram with results of elemental analysisof some kerogen from Agbada and Akata shales of Niger Delta

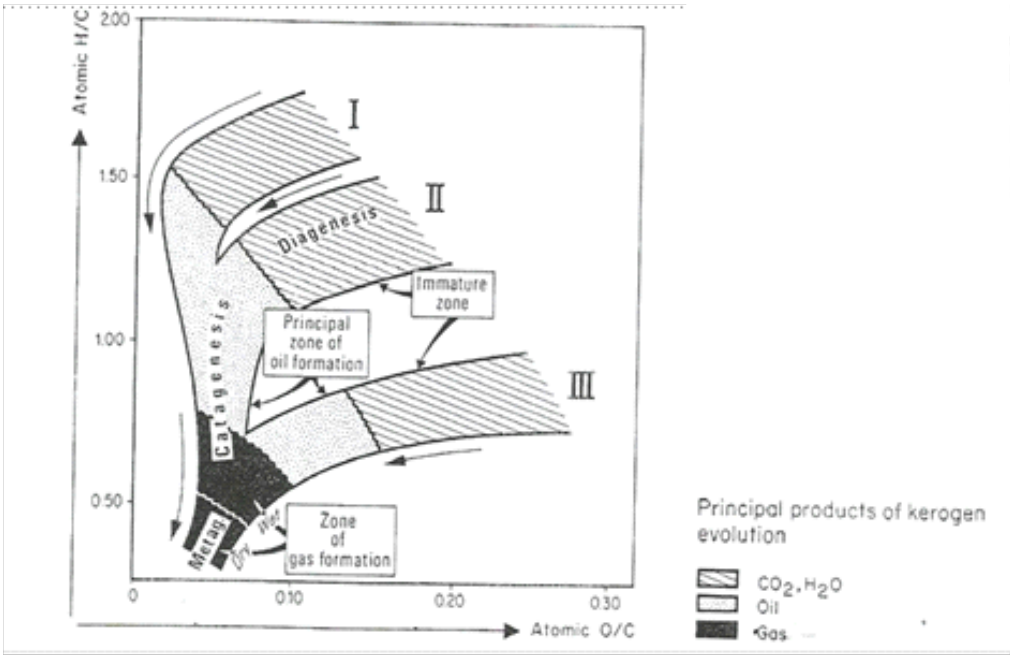


Fig. 10: General Scheme of Kerogen evolution presented on van Krevelen's diagram. The successive evolution stagesare indicated and the principal products generated during that time. (Modified after Tissot, 1973).

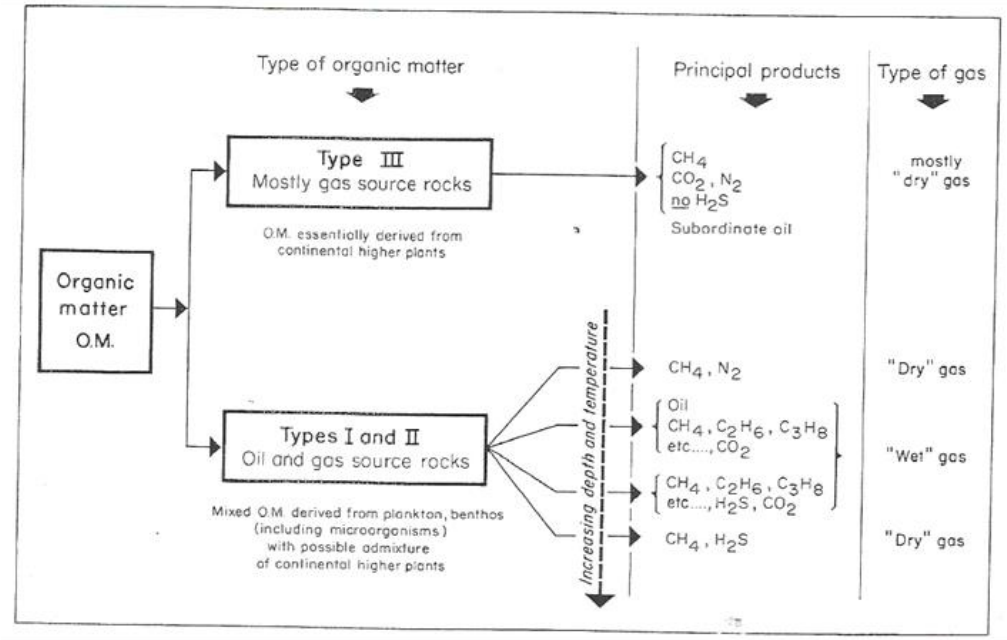


Fig. 11: Gas sources rocks and oil source rocks: influence of the organic input and of the burial history. (From Tissot and Welte, 2004)

Omotoye et al (2016), using GC-MS, analysed a total of 17 crude oil samples from producing wells in the eastern Niger Delta for their thermal maturity status and concluded from the pristane/phytane (Pr/Ph) ratio which ranged from 2.3 to 5.1 that the oils were derived from mixed terrigenous/marine organic matter(Type II).

From this author's work on the occurrence of organic matter in Carbonate sediments, I infer that the differences in composition of macerals can be attributed to some "harsh" extraction techniques usually applied by some workers in the isolation of organic matter from samples. Such methods "consume" much of the more labile and "more vulnerable" organic matter of marine origin leaving the extract in this case with a preponderance of terrigenous organic matter. In the study of carbonates, it gave the erroneous impression that carbonates are organic matter poor. (see Ibe, 1980; Ferguson and Ibe, 1981, for detailed discussion of organic matter extraction techniques).

The oil-prone character of kerogen types I and II and the essentially gas-prone character of kerogen type III and coal are also well known from experimental geochemical data. The statistical verification of this difference in the geologic environment of the Niger Delta is reflected by the fact that several directional trends form an "oil-rich belt" having the largest field and lowest gas: oil ratio (Ejedawe, 1981; Evamy and others; 1978; Doust and Omatsola, 1990). Weber (1987) referred to this oil-rich belt as the "golden lane."

Tissot and Welte (2004) affirmed that, "---the frequently discussed question of oil versus gas provinces is linked to the genetic characteristics of the organic matter. They went on to state that "---in general, the organic matter incorporated in marine or lacustrine sediments is derived from natural associations of flora and fauna, and it has been mixed and homogenized by natural processes of sedimentation (in rivers and marine currents) and by microbial activity. This situation corresponds to the "high evolution paths" on the Van Krevlen Diagram (kerogen type I or II) **(figs 10&11)**

Authors (e.g. Ekweozor and Daukoru, 1984) who have sought to describe the organic matter of the Agbada paralic sequence as exclusively Type III seem to imply a sterile sea into which terrigenous organic matter was deposited. This is inconceivable. As Landes (1960) put it, "--- it is extremely unlikely that there has ever been a sterile sea since life first appeared on earth."

In fact, it is known from present day studies of the dynamics of offshore Nigeria, that this is an environment of upwelling phenomenon that overtime has generated prodigious amount of nutrients (organic matter) in this environment (Ibe and Ajayi, 1985). Studies from space platforms have confirmed the Gulf of Guinea as one of the most prolific areas of primary productivity (Ukwe et al, 2006; Ukwe and Ibe, 2008)

It has been stressed that organic matter in source rocks almost always contains a mixture of kerogen types**.** However, Ulmishek and Klemme (1990) have noted that usually one type of kerogen is predominant or at least more abundant.Rodgers (1979), has pointed out that in cases where a significant proportion of the organic matter incorporated in marine sediments originates on land, it may bear a characteristic terrestrial carbon isotope and

hydrocarbon composition signature.This would explain the high pristane:phytane ratios in the oils of the Niger Delta. Tuttle et al (1999) has noted that, "If the oils are derived from terrestrial organic matter younger than mid-Cretaceous, then the oleanane:C_{30}-hopane ratios are high as well."

The biostratigraphic assemblage of the Akata Group shales resembles open marine, distal delta slope environment (Adegoke et al,1976; Harris,1981; Larsen,1980; Petters, 1982, 1983a,1984). This environment of deposition would have dominantly Type I with sparse contribution from Type III organic matter as is reflected by present day studies of similar environments.If Akata shales were indeed the source, the Niger Delta petroleum would be dominantly heavy crudes with high sulphur contents in conformity with the Type I organic matter.This is not the case.

It would be a contradiction to propose that the oils which show dominant Type III "fingerprints" would be sourced from the open marine shales of the shales of Akata Group.Assertions by Stacher(1995) that, "---marine clays (Akata Formation)accumulated in restricted basinal areas during sea level low stands, can contain higher amounts of land -derived organic material and are the main Niger Delta source rocks---"are not borne out by our knowledge of basicOceanography including characteristic biostratigraphic assemblages of this "Formation". Stacher'smisleading interpretation is a restatement of earlier erroneous views of an Akata source and has only served to muddle the debate. In fact, the claim of the dominance of Type III in macerals is a confirmation of an environment of deposition consistent with paralic sequences and supports an origin in Agbada shales.

1(b).1. Vitrinite Reflectance and Maturity

Ekweozor and Okoye (1980) published vitrinite data based on which they established maturity cut off pointswhich tended to show that the shales of the Agbada Group are immature. While reflectance data as an index of maturity of study samples are reliable, it must be pointed out that the recommended minimum reflectance R_O=0.6(Dow, 1978) is largely empirical and arbitrary because as McCartney and Teichmuller(1972) have pointed out, maturation values may vary between R_0=0.3 and R_0 =0.8 depending on the type of Vitrinite. As an example, desmocollonite type of vitrinite would show much lower reflectance values when compared to sample rich in telocollinite at a specific degree of carbonization. This is borne out by vitrinite reflectance data of Fisher (1979) which showed that samples from as shallow as 1,599m in many wells attain R_0 = 0.5 for the western Niger Delta.

According to a discussion in Lambert-Aikhionbare and Unomah(1995), Ekweozor and Udo(1987) established a maturity index, the oleanane index, and correlated this novel index with the delineated top of the oil generative window in wells based on which they noted that thetop of oil generative windowhad matching vitrinite reflectance of about 0.4 – 0.5 %.Lambert and Unomah (1995) commented that, "--- it confirmed recent observations that most biomarker indices that are commonly used in maturation studies are not sensitive enough for Tertiary sediments and that oil generationin parts of the Niger Delta occurred at a lower vitrinite reflectance than the arbitrary cut off of 0.6 %."

2. **The convertibility of the organic matter to oil under the physico-chemical conditions present in the source bed**

In general, convertibility of organic matter depends on availability of hydrogen atoms and the molecular structures of the organic compounds in addition to the thermal energy supply.

Initiation of chemical reactions essential to convert part of the organic matter into petroleum hydrocarbons occurs only after considerable geothermal energy is supplied to the organic matter (kerogen)through the sediment on attainment of considerable depths and with increase in the exposure time.

Considerable depth of burial (with the concomitant elevated temperatures) is a key plank upon which the Akata shales are preferred as source rocks. However, the Akata shalesare far from normal.The 37 samples analysed by Lambert -Aikhionbare and Ibefor thermal maturity included 4 samples from the Akata Group which were found to be thermally immature. This was hardly surprising. Numerous studies of kerogen isolated from over pressured shales have revealed them to be nearly always immature. (see account by Neglia, 1980). Neglia cited Agip's Cononica 1 in western Germany in which the kerogen isolated from the over-pressured Triassic shales is still immature even at depths of 7,110 m despite measured temperatures as high as 200^{o} C. Barker (1972) and Sengupta (1974) have shown that pressure is an important factor in chemical reactions which occur during the maturation of organic matter. Independently, they advanced the theory that most organic matter maturation processes proceedwith small volume increases and, therefore, would be inhibited by pressure.

Lambert-Aikhionbare and Ibe (1984), therefore, concluded that it is highly unlikely that the distinctly over-pressured shales of the Akata Group would have generated expellable hydrocarbons.

It is significant to note that results from more recent pyrolysis experiments of immature Type II and IIs kerogen (eg Kimmeridge Clay, Dorset UK, and Monterey shale, California, USA respectively) showed that pressure retarded both maturation and petroleum generation (Carr et al. 2009; Landais et al.1994; Michels et al. 1995; Uguna et al. 2012a, 2012b, 2015; Uguna et al,2016) (see discussions in Section 4 below).

Nwachukwu and Chukwura (1986) analysed shale samples from 3 wells in western Niger Delta for their organic matter content and maturityand concluded that "--- about 900m of mature Agbada shales are present in the western part of the Niger delta. These shales contain kerogen that may be oil prone, because of the abundance of amorphous organic matter, and could have been a source for some of the oil found in the Makaraba, Abiteye and Okan fields."

Many authors have suggested minimum depths of burial varying between 1000 to 5000 ft necessary for petroleum formation but there are myriads of exceptions. Teas and Miller (1933) reported origin and accumulation of oil at Racoon Bend that took place under an overburden equivalent to only 450 ft of the presently overlying section. On their own part, Kidwell and Hunt (1958) found evidence for the concentration of petroleum like hydrocarbons in a sand lens in Recent clays at a depth of only 110 ft.

Hedberg (1964) who summarized the opinions concluded that, " there seems to be little reason in direct pressure effects alone for postulating any minimum depth of burial

requirements---“ and noted that “---shearing or folding pressures developed tectonically may locally have been much more potent than gravitational pressure”

It is known that persistent high- or low-temperature anomalies can alter the otherwise predictable burial depth requirements for petroleum generation, maturation and expulsion(GME).For example, local “hot spots” associated with hydrothermal activity, igneous intrusives and extrusives, tectonism, diapirism, or highly heat-conductive sediment may result in GME at somewhat shallower depths than normal conditions would permit(Momper and Williams, 1970) . The deposition of the paralic Agbada sequences was accompanied by intense diapirism and faulting which formed the anticlinal folds that are the petroleum traps. The prograding Niger Delta causes extensive gravity spreading with the offshore manifestation of this gravity-driven deformation consisting of substantial extension of the shelf and inner slope, and contractional folding and thrusting in the outer slope and basin floor (Merki, 1972; Lehner and De Ruiter, 1997; Evamy et a,1978; Doust and Omatshola, 1990; Datmuth, 1993, Corredor et al, 2005; **fig 12**). The continental margin has undergone deformation by gravity tectonism caused by rapid seaward sediment propagation. Deep-seated gravity sliding of the continental slope generated three different regional structural styles to be recognized (**see fig13**).

Could this tectonism admit of the existence of “local hot spots” that could have accelerated GME at shallower depths?

2.1 The Role of Catalysis and Radioactivity

Again, concerning depth of burial and temperature requirements, two phenomena, catalysis and radioactivity, recognized widely by several authors as pertinent in “speeding up” thermo-chemical reactions in organic matter, have largely been ignored in discussions of depth -temperature requirements for the maturity of organic matter in the Niger Delta.

It is known that catalysts are introduced in petroleum refining operations to expedite reactions at lower temperatures than might otherwise be possible. A similar role has been attributed to certain catalysts which occur in either the organic matter or the enveloping sediments in the transformation of organic matter into petroleum hydrocarbons. Brooks (1954) canvassed such a role for acid silicates and attributed differences in the composition of petroleum’s to most probably the differences in catalytic activity of the rocks and minerals with which they have been associated.Similarly, Landes(1959) asserted that, “certain minerals such as acid silicates, acted as catalysts through geologic time” while Dobryansky (1963) stressed the significance of aluminum silicates. These silicates occur in the clays and shales of the Niger Delta.(Porrenga,1956;Lambert-Aikhionbare and Shaw, 1982)

Mango (1997) who carried out studies of metal catalysis (based on Ni) in source rocks showed that various transition metal compounds in the pure state are very likely the active agents in source rocks that catalytically generate natural gas in the laboratory. He noted the rather robust nature of the catalysis because, “ --- water, air, and CO_2, which are generally powerful poisons in metal catalysis, have little or no effect on the catalytic properties analyzed--.” He emphasized that Ni was selected for the experiments, “--- because it exhibits catalytic properties similar to other first- row transition metal oxides, in particular V, Co and Fe.”

As for Radioactivity, it has been known that hydrocarbons could be produced in the laboratory by bombardment of organic compounds. In his review of the subject, Levorsen(1963) stated that, "the radioactive elements, Uranium, thorium, and potassium, were known to provide an almost universal source of radiation in the environment of organic accumulations---."

From the geology of continental Nigeria, the occurrence of mineral deposits which would supply catalyzing minerals like Ni, V, Co, Mn, Fe, Cu and Mo, and radioactive elements e.g Uranium or its breakdown elements, is well documented. It is obvious that they have been contributed to the marine environment through geologic time as leachates via terrigenous input from the various rivers that drain inland Nigeria before emptyinginto the marine environment.

Under conditions of catalysis and radioactivity, overly reliance on depth of burial and thermal gradients such as those calculated by Avbovbo (1978), Evamy et al (1978) and Edjedawe et al (1984) among others as indices for kerogen maturation profiles would not be tenable. It is that notion that has led workers to insist, erroneously, that the Agbada shales will be immature at depths in which they occur.

3. The efficiency of the expulsion mechanism

There is almost universal agreement among petroleum geologists that expulsion of oil from source rocks is an inefficient process. Momper and Williams (1970) summarized the numerous work in this field by stating that, "an effective source bed retains considerably more than half of its generated oil after oil expulsion ceases. Most source beds release only about 5% to 15% of generated oil. Source bed efficiency in excess of about 30% has not been observed."

Sediment dewatering is considered necessary for efficient expulsion of liquid petroleum from its source beds. For each barrel of liquid petroleum expelled, it is estimated that about 50 bbls or more of water must be expelled to provide a carrier medium (Momper and William, 1970).

There is an implication of early generation and expulsion of petroleum hydrocarbons from compacting sediments. Writing on the subject matter, Banks (1966) submitted, "that thereis considerable evidence, largely obtained in the last 15 years, that oil formed early and that as such, or as a petroleum like substance, it completed its primary migration relatively soon after the deposition of the source materials as a result of fluid expulsion from compacting sediments". Similarly, Herdberg (1964) had noted that, "---the subsequent expression of a large part of contained water from sediment through compaction, appears to be a critically essential accompaniment to the formation of substantial petroleum accumulations. Both are simple, well substantiated, directly observable, and almost inevitable physical processes so that nothing hypothetical is called for in assuming their operation"

It is known that compaction occurs early and rapidly in fast depositing basins and the expulsion of fluids from compacting sediments seems to be the most logical explanation of primary migration in situations where source and reservoirs are different.

It is known that overpressures result when the interstitial fluid cannot be expelled. The fluid is over-pressured and the rock matrix is under-compacted.

Data from Schlumbeger (1985) show that the pressure level in the under-compacted Akata shales is at least one and half times the normal hydrostatic pressure.

Yorder (1955) and Barker (1972) among others have argued that the removal of only a small percentage of the pore fluid from an over-pressured zone reduces the abnormal pressure to the hydrostatic pressure for that depth. Lambert-Aikhionbare and Ibe (1984) have asserted that the fact that the Akata Group is still under-compacted and over-pressured to this day denotes that only little fluid, if any, had been expelled from such lithologic unit. This would seem to favour the contemporaneous shales of the Agbada Group as the source rocks rather than the under-compacted and over-pressured shales of the Akata Group.

Some authors like Lewis and Rose (1974) have proposed that temperature is dominant even in over-pressured conditions such as typify the shales of the Akata Group. Assuming a scenario of the organic matter in Akata shales as mature (i.e. within the oil generation window as calculated by Evamy,1978; Edjedawe, 1984) one great impediment to the postulation of the Akata shales as the major source rocks in the Niger Delta is the lack of a credible mechanism for the expulsion of any generated hydrocarbons to the distal reservoirs in the Agbada Group. The Akata ranges in thickness from 2000- to 7,000m. Ejedawe and Okoh (1981) calculated expulsion rates of 12 percent from the Akata shales in contrast to 35 percent for Agbada shales. In his review of the expulsion mechanism, Tuttle et al (1999) cites an explanation given by Hunt (1990) to account for the migration of hydrocarbons from mature over-pressured shales in the Gulf of Mexico to the more distal portion of the delta. According to them, "Hunt (1990) relates episodic expulsion of petroleum from abnormally pressured, mature source rocks to fracturing and resealing of the top seal of the over-pressured interval. In rapidly sinking basins, such as the Gulf of Mexico, the fracturing/resealing cycle occurs in intervals of thousands of years. This type of cyclic expulsion is certainly plausible in the Niger Delta basin where the Akata Formation is over-pressured". This "open and shut" operation separated by thousands of years, espoused by Hunt (1990) would seem to be a desperation move to create something out of nothing. Nature just does not work that way and there are no known laboratory demonstrations of this proposed esoteric mechanism.

Similar "desperation theories" were offered to prove that hydrocarbons found in Carbonate petroleum systems originated in shales so removed in time and space as to defy rational thinking.

4. The critical release range

A minimum quantity of hydrocarbons must be generated before a source bed can expel its petroleum. This minimum is called "the critical release range". It is thought to vary with the characteristics of each source bed. To our knowledge, no calculations exist for this minimum in the Niger Delta but data from other petroleum producing basins indicate about 10-15 bbl/acre-foot but may be as low as 7.5 bbl/acre-foot under highly favourable conditions (Momper and Williams,1970).

Given the severely limiting conditions imposed by the over-pressured and under-compacted nature of the Akata shales, it is doubtful that these shales have either generated sufficient quantities of hydrocarbons or undergone appropriate dewatering process to

overcome the attractive forces between the petroleum and other sedimentary materials to attain a critical release range. The data of Lambert-Aikhionbare and Ibe (1984) which found all 4 samples from the Akata Group to be thermally immature would seem to buttress this point.

More recently, Uguna et al (2016) conducted pyrolysis experiments on immature Type II and IIs source rocks (Kimmeridge Clay, Dorset UK, and Monterey shale, California, USA respectively) that showed that high water pressure significantly retards petroleum generation, source rock maturation and vitrinite reflectance. It was a reaffirmation of earlier results from similar experiments (Carr et al. 2009; Landais et al.1994; Michels et al. 1995; Uguna et al. 2012a, 2012b, 2015). "The retardation of oil generation and expulsion---," they wrote, "---resulted in significant amounts of bitumen and oil being retained in the rocks pyrolysed at high pressures, suggesting that pressure is a possible mechanism for retaining petroleum (bitumen and oil) in source rocks--." Uguna et al (2016) noted the significance of their findings because, "geochemical models currently used to predict petroleum generation and source rock maturation assume that both petroleum generation and source rock thermal maturation are determined by the thermal history of the source rock alone (e.g. Pepper and Corvi, 1995), with pressure being considered to have no effect." They examined the discrepancies and attributed them to the different pyrolysis techniques used (see Ugunna et al, 2012a and Carret al 2015 for comprehensive examination of pyrolysis techniques) and concluded that, "---the implications from this study are that in geological basins, pressure, temperature and time will all exert significant control on the extent of petroleum generation and source rock maturation for Type II source rocks---"

Previously, Osborne and Swarbrick (1997) had examined some propositions that hydrocarbon generation and cracking to gas could possibly produce overpressures but found that these processes may be self-limiting in a sealed system because buildup of pressure could inhibit further organic metamorphism. They concluded that the potential for generating overpressure by hydrocarbon generation and cracking "---must be regarded as unproven at present" and favoured loading during burial as the process generating considerable overpressures due to disequilibrium compaction, particularly during the rapid subsidence of low permeability sediments.

5. THE WIDE VARIATION IN HYDROCARBON PROPERTIES BETWEEN AND WITHIN OIL FIELDS

The physical and chemical properties of the oil in the Niger Delta are highly variable, between & within fields even down to the reservoir level to attribute them to one single source, the Akata shales. They also have different gas/oil ratios.

Tuttle et a l(1999) summarized the properties of crude oil of the Niger Delta as follows:
"Organic geochemical profiles for a non-biodegraded and moderately biodegraded Niger Delta---[show]the oil within the delta has a gravity range of 16-50° API, with the lighter oils having a greenish-brown color (Whiteman 1982). Fifty-six percent of Niger Delta oils have an API gravity between 30° and 40° (Thomas, 1995). Most oils fall within one of two groups. The first group are light paraffin based, waxy oils from deeper reservoirs (wax content up to 20%, but commonly around 5%; Kulke, 1995; Doust and Omatsola, 1990; high n-paraffin/naphthene of 0.86). The second group of oils are biodegraded and from

shallow reservoirs. They have lower API gravity (average API of 26°; Kulke, 1995) and are naphthenic non-waxy oils (n–paraffin/naphthene = 0.37)".

Although Welte (1965) argued that, "--- one source rock can deliver a whole series of different crude oils---[because] of the progressive thermal –degradation of the organic materials---, "this does not seem to be the case here. Regarding variations in oil gravity and composition, Herdberg (1964) wrote, "Variations in properties from one oil to another may of course commonly result from secondary alterations --- in many cases the evidence seems to be very strong that variations may be due to differences in original source. In a sequence of closely related oil sands of essentially the same age in a single field, separated by relatively impermeable shales or water barriers, marked non-systematic variations in density, viscosity, refractive index, fluorescence, color, odor, wax content, and chemical composition, strongly suggest local differences in source material or source conditions."

II. GEOLOGICAL ASPECTS

II.1. MIGRATION PATHWAY

As reported by many workers, faulting in the Niger Delta is principally syn-depositional and appears to have affected mostly the paralic succession. Growth faulting is interpreted as triggered by the movement of deep seated, over-pressured, ductile marine shales. Such phenomenon occurs during delta progradation. According toTuttle et al (1999), "---these faults mostly offset different parts of the Agbada Formation and flatten into detachment planes near the top of the Akata Formation."

Even though it is not clearly demonstrable within the Akata shales(penetrating perhaps not beyond the normally compacted section of the Akata Group)but such faults have been cited as possibly playing some role in the migration of hydrocarbons from presumed Akata source rocks**(figs 12 & 13).**Weber and Daukoru(1975)indicated that some synsedimentary faults contain alternating clay and sand laminae which, although they may inhibit across-fault migration, may allow migration along the planar fault.On his own part, Stacher (1995) assumes migration overlaps in time with the burial and structure development of overlying reservoir sequences and occurs primarily across and up faults.

The up-fault migration presented by Weber and Daukoru (1975) & reiterated by Ekweozor and Okoye (1980) and Stacher(1995) as the mechanism for the transfer of hydrocarbons from Akata shales is questionable.As pointed out already, such faults are known to penetrate only a short distance into the Akata.Migration along faults in the region is further discredited by the extensive smearing of shale along the faults, as recognized by Weber and Daukoru(1975) and Doust and Omatsola (1990), as the dominant hydrocarbon trapping mechanism.

Similar sealing mechanisms have been described in Graben hydrocarbon occurrences and structural styles by Harding (1984) from his study of the Sirte(Libya) basin, the Suez(Egypt) and Viking (North Sea) grabens. Even though the geometries of these traps and controls for their development may differ somewhat, a similarity exists because in many cases the hydrocarbons within the graben-fill reservoirs are partially trapped against the upthrown side of the block -bounding faults which form effective barriers to migration

of hydrocarbons. Harding (1984) noted that "---each of the three basins has the capacity to contain major hydrocarbon reserves where there has been deposition of reservoir facies and source rocks, or in some cases (carbonates), just deposition of reservoir rocks". It is instructive that the faults bottom out in the crystalline basement therefore ruling out any updrift migration of hydrocarbons from such rocks.

Many workers have argued that migration from source is rarely long distance (eg. Banks, 1960; Herdberg, 1964; Momper and Williams, 1970). In the Niger Delta, in particular, evidence that migration pathways were short have come from the wax content, API gravity, and the chemistry of oils (Short and Stäuble, 1967; Reed, 1969).Fuloria (1967) has stressed that "from point of view of petroleum emigration of hydrocarbons, alternation of permeable rocks like sandstones ---with mother rocks should be regarded as a more favourable criterion than a thick monotonous section of source rocks."

II.2 Evidence from Biostratigraphy

Another support of the Agbada shales as major source rocks in the Niger Delta has come via the study of Reed (1969) who, in an attempt to test Hedberg's suggestion that high - wax oils may reflect the contribution of terrigenous organic matter to the genesis of petroleum.

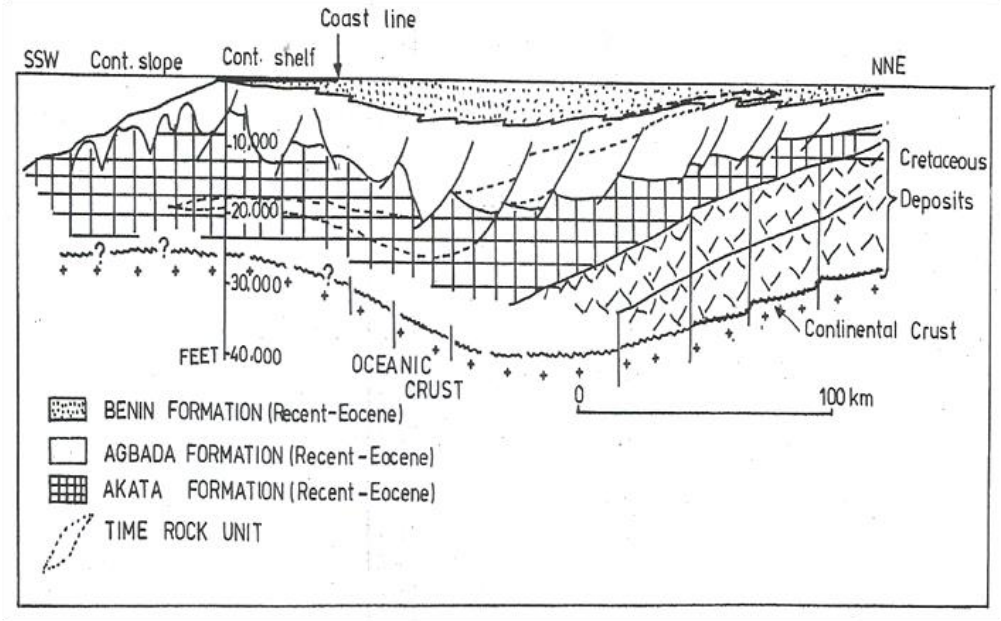
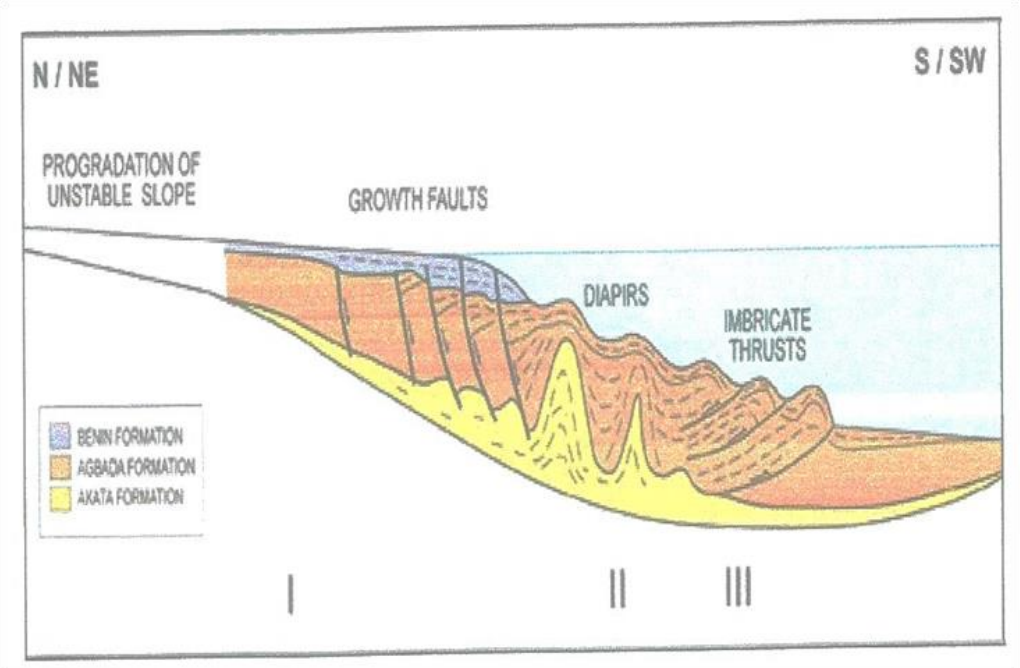


Fig. 13: Schematic cross section showing principal stratigraphic units of Tertiary Niger Delta (adapted from Merki, 1972)

Fig. 14: Schematic cross-section through the Niger Delta: 1- Upper Extensional Zone; II-Translational Zone; III - Lower Compressional zone (Ajakaiye, and Bally, 2002)



tested 41 samples from offshore wells in the western flank of the Niger Delta. Using the relative abundance of arenaceous and planktonic foraminifera and total foraminiferal population, he evaluated the environment of deposition not only for each oil bearing sandstone, but also for the beds adjacent to those sandstone beds (i.e. the shale beds). He concluded that, "the environment of deposition, therefore was such that terrigenous organic matter would be relatively abundant and thus according to Hedberg's hypothesis, high wax oils would be expected." Reed's Table II (p.1505 reproduced here as **Table** 4.) shows that the majority of the Nigerian High pour-point (=high wax) oils studied confirmed Hedberg's hypothesis. Reed asserted that these high wax oils are associated with continental, paralic or nearshore -marine environment. If the origin of these oils was the open marine depositional environment, of the Akata shales, low wax oil would have been the case. Hedberg (1968) had asserted that "in general, the sequences which have yielded high wax oils produce low Sulphur rather than high sulphur crudes. This is true for much of Nigerian crudes which have low sulphur content.

II.3 Evidence from Diagenetic Studies

Further support for the Agbada Shales as the major source rocks in the Niger Delta has come from the study of the significance of clays in the petroleum geology of the Niger Delta, by Lambert-Aikhionbare andShaw (1982). They wrote:

"in the Agbada formation, there are significant differences between the clay mineral assemblages of the water- bearing and the hydrocarbon-bearing sandstone reservoirs. In the latter, the early migration of hydrocarbons into the reservoir sands limited the development of authigenic clays, preserving the early formed authigenic kaolonite and preventing its corrosion and the formation of authigenic smectite---as found in the water

bearing sandstones." The authors concluded that, "this is evidence for the early migration of hydrocarbons which also lends support to the concept of the generation of hydrocarbons in the paralic Agbada shales adjacent to the reservoir sandstones rather than in the more distant Akata shales."

Table 4: Pour Points of oils and Foraminiferal Numbers in oil-Bearing Sandstone and Adjacent Rocks in some Nigerian Wells

Well	*Depth (Ft)*	*Pour Point (°F)*	*Foraminifera**			*Category***
			Arenaceous	*Planktonic*	*Total*	
Delta-1	5,800–5,850†	−24	—	—	144	B
	6,170–6,230†	−26	—	2	76	B
	7,000–7,050†	3	40	16	204	D
Delta South-1	5,940–5,960†	60	108	40	600	A
	6,040–6,080	55	2	8	32	A
	6,200–6,250	55	14	136	308	D
	6,350–6,420†	60	16	2	142	A
	6,935–6,955†	57	76	40	180	A
	7,350–7,470	60	32	48	220	A
	7,885–7,925†	75	96	52	944	A
	8,050–8,100†	56	82	34	266	A
	8,200–8,280†	65	18	36	220	A
	8,990–9,020	60	12	28	272	A
	9,229–9,255	65	156	72	1700	A
Mefa-1	7,340–7,390	55	17	10	173	A
	9,370–9,420	60	14	4	196	A
Meji-1	5,450–5,590†	−20	3	37	157	B
	6,780–6,890†	43	24	31	169	C
	7,400–7,520†	53	96	54	280	A
	9,050–9,120	50	114	186	594	A
	9,830–9,995	50	34	159	368	D
Meren-1	5,290–5,335†	−35	28	136	480	B
	5,920–6,110	10	38	147	560	B
	6,700–6,810	55	124	69	460	A
Mesan-1	5,525–5,620	10	5	30	110	B
	6,010–6,050	60	—	4	36	A
Okan-4	5,280–5,320†	25	—	—	72	D
	5,655–5,670†	15	8	72	800	B
	6,208–6,255	−30	2	140	358	B
	6,320–6,360†	−17	4	32	134	B
	6,540–6,560†	10	—	48	312	B
	6,670–6,740	15	4	76	184	B
	6,810–6,870†	25	8	32	142	B
	7,860–7,950†	−30	6	28	144	B
	8,035–8,090†	60	2	6	50	A
	8,575–8,620†	62	—	12	72	A
	8,720–8,830†	60	8	13	72	A
	9,040–9,075†	−20	—	—	4	D
	9,530–9,690	70	3	375	823	D
	10,190–10,262	75	—	2	122	A
Olongo-1	8,740–8,760	7	26	4	82	D

* Numbers in a 200 gm cuttings sample over the interval considered (with the limits imposed by a sampling interval of 60 ft).
** Type of oil-bearing sandstone (see text).
† Pour-point data obtained from other wells in same field and applied to same sandstone interval in well listed.

III.4. Unfaulted Stratigraphic Traps

Furthermore, the presence within the Agbada Group of unfaulted stratigraphic accumulations eg Egbema West Field (see Fig 6) discountenances the claim by Weber and Daukoru (1975) supported by Ekweozor and Okoye (1980) and Stacher (1995) of long range up-dip migration of hydrocarbons from the deeply buried marine Akata shales into the distal reservoirs of the Agbada Group. Beka and Oti(1995) demonstrated that on the flanks of the Delta, stratigraphic traps may be as important as structural traps.

A WORD ON A POSSIBLE "DUPLEX THEORY" OF NIGER DELTA HYDROCARBONS.

Weber and Daukoru, while proclaiming Akata shales as the major source rocks admitted that the lower part of the paralic Agbada shales found at appropriate depths could have served also as source rocks. Evamy et al(1978) claimed that the lower parts of the paralic Agbada shales and the marine Akata shales are both source rocks in the Niger Delta but doubted that the Agbada shales had the thickness to constitute world class oil fields. Ekweozor and Okoye (1980) and Ekweozor and Daukoru (1984) in backing an Akata shales as main source have stated that the lower sections of the Agbada shales could have generated hydrocarbons. Relying on maturation models, Ejedawe et al. (1984) concluded that the Agbada shales are the source rocks in the central part of the Niger Delta whereas the marine Akata shales are the source of the gas. They claimed that in other parts of the Delta, both shales serve as source rocks for petroleum Hydrocarbon oil. On their own part, Doust and Omatsola (1990) asserted that both the Agbada and Akata shales have served as source rocks and even favoured the Agbada shales as supplying the bulk of the hydrocarbons.

So, it means that it is not all black and white in the controversy of the origin of Niger Delta petroleum. However, this review was about resolving the "major source" designation and relied on the preponderance of evidence one way or the other. Stacher (1995) has argued, much like Evamy et al (1978), that the Akata shales are the only ones that are volumetrically sufficient and whose depth of burial is consistent with the depth of the calculated oil window to generate enough oil for a world class oil province such as the Niger Delta. Those who make these arguments about "size" fall victim to the erroneous descriptions of the Agbada shales as "intercalations" of shales with the sandstone reservoirs of the paralic sequence. In reality, however, these shales are "alternations" of the shale-sandstone sequence of the Agbada Group and are sufficiently thick in many places (see fig 7) to account for the petroleum hydrocarbons found in the contiguous sandstone reservoirs.

Also, the higher convertibility of organic matter can make up for volumetric deficiency. The higher petroleum generation efficiency of kerogen types I and II is well known from experimental geochemical studies and mass balance calculations (Hunt, 1979; Kontorovich and others, 1975). According to Tissot and Welte (2004), the generation potential of the hydrogen rich Type II is about three times the potential of the hydrogen -poor Type III. Our study of the dominance of oil fields show that this disposition is also statistically correct for thegeologic environment of the Niger Delta as it is for similar environments worldwide.

SUMMARY

The evidence adduced in this Paper in support of the Agbada School include, (a) sufficient quantities of the oil prone Type II organic matter in the Agbada shales, (b),the thermal maturity of organic matter extracts from the Agbada shales,(c)the wide variation in hydrocarbon properties between and within beds which point to different sources,(d) the presence within the shales of unfaulted stratigraphic accumulations e.g. Egbema West Field,(e)the evidence of early migration and accumulation of the Niger Delta petroleum deduced from diagenetic studies,(f)the predominance of high pour-point (=high wax) consistency of the majority of Nigerian oils,(g)experimental evidence that show that catalysis and radioactivity can compensate for shortfalls in depth requirements,(h) etc.

On the other hand , factors militating against the Akata School include,(a) the decidedly under-compacted and over pressured nature of the Akata shales, (b) the thermal immaturity of the organic matter extracts from the Akata shale,(c)the absence of any expulsion mechanism for any hydrocarbons generated, if at all, within the Akata shales, (d)the lack of a credible migration pathway for any hydrocarbons supposedly generated within the Akata shales, (e)the wide variation of properties of oils from reservoir to reservoir, between and within fields, which would tend to preclude a unique source for the variegated hydrocarbons in the Niger Delta, (f) recent experimental evidence that pressure retards kerogen maturation, generation and expulsion as well as inhibithydrocarbon cracking reactions, (g) etc.

The present review marshaling evidence in favour of the Lambert- Aikhionbare and Ibe School of Thought (i.e. the Agbada Group as Major Source Rocks) has been undertaken, not from a point of view of dogma, but in a hope to rekindle the kind of stringent enquiry that Chukwuemeka Ekweozor, Edmund Daukoru, Emmanuel Egboga, Joe Ejedawe, Daniel Lambert- Aikhionbare, Joseph Nwachukwu, Layi Fatona and I (among others) undertook in thelate1970s and beyond. This is especially so as more recent publications on the Origin of the Niger Delta Petroleum have tended to back a duplex theory of the origin of the Niger Delta hydrocarbons, i.e. from the shales both of the Akata and Agbada Groups.

My view is that accepting this kind of "compromise" without additional hard evidence in support of or against one School or the other, is not good for Science!

A call is made here for additional in depth multi-disciplinary and trans-disciplinary studies of the Origin of the Niger Delta Petroleum. The more clarity is brought to this debate, the greater the chances of finding additional petroleum reserves to underpin the diversification of the petroleum industry for robust national economic growth and social development of our people.

The old saying in the Oil Industry, "IF YOU KNOW HOW IT ORIGINATES, YOU KNOW WHERE TO FIND IT" still rings true!

AN UNFINISHED BUSINESS

Between 1995 and 1999, an Inter-Agency Stratigraphy Committee of the Niger Delta aimed at validating and integrating the various biostratigraphic schemes. Some results are shown in **Figs 14 & 15.** even if they still utilize Evamy et al (1978) alphanumeric coding **system because the work of the Stratigraphic Committee is not yet complete.**

As one who was in the Petroleum industry in the mid 1970ss, I can testify that interpretingthe sub-surface stratigraphy of the Niger Delta was almost like a stab in the dark--- few wells, poor seismic data, disparate palynologic and paleontologic correlations, etc.

Today, the delta is covered with a dense grid of 2-D and 3-D seismic data & has been penetrated by more than 5,000wells. In addition, the improved tie of biozones to the radiometric time-scale has considerably improved accuracy of detailed stratigraphy. A modified facies model reflects deltaic sedimentation patterns as a function of the rates of

(a) Deposition, Rd (b) Subsidence Rs (c) Eustacy (sea level rise) Re rather than the old model which relied on Deposition and Subsidence episodes alone (Reijers, 2011).

The stratigraphic section of the Niger Delta presents evidence for long- and short-term sea-level variations that interacted with each other. Thirty-nine eustatic sea-level rises are reflected in the Niger Delta, nineteen of which are named and eleven of which occur delta-wide. These produced sinusoidal sediment bodies or genetic mega-sequences that are marked at the base by delta-wide transgressive shales

Reijers explained that the "genetic mega-sequences are interpreted to reflect allocyclic events superimposed on which occur a series of auto cyclic events."

Reijers who had presented these proposals first to the AAPG Conference in Vienna and subsequently at the NAPE Conference in Lagos both in 1997, posited that the megasequences are the key lithological elements of the Niger Delta and the starting point for a new Delta wide litho-stratigraphy. He proposed that:
Each genetic sequence be called a Formation. Two examples from his detailed presentation would suffice.
The Middle Eocene (54.6–38.0 Ma) *Eponides*-11 genetic mega-sequence
Stratigraphy
Within the *Eponides*-11 mega-sequence, three lithostratigraphic units are candidates for formation rank: the basal *Eponides*-11 and the intermediate Umutu transgressive shales, and the glauconitic marker sand.
The Pliocene-Holocene (5.0-0.0 Ma) *Bolivina*-46 genetic megasequence
Stratigraphy
The *Bolivina*-46 megasequence contains the candidate Qua Iboe Formation, that has been subdivided by Mobil into the Biafra Sand, the Rubble Bed and the Qua Iboe Clay Members. For those inclined to contest the relatively smaller size of the proposed new Formations, it is worth noting that according to the American Commission for Stratigraphic Nomenclature (ACSN), thickness of a Formation is not a determining feature in its discrimination. A Formation of 10 ft may be adjacent to another of 5,000 ft thick.

As a general routine, as work progresses in a given Region, it often becomes desirable to change the rank of a Unit, without changing its content of rocks-for example, the Mesaverde Formation of early work on the Mesa Verde, Colorado, became in later work the Mesaverde Group, containing several formations (Herdberg,1964)

Thus, the hitherto designated Benin, Agbada and Akata Formations, would logically be called Benin, Agbada and Akata Groups. Herein lies the justification for the preferred term GROUP used in this discourse.

Reijers declared that, "A new litho-stratigraphy is badly needed in particular because of the vigorous new activity in the offshore part of the Niger Delta --- the traditional lithostratigraphic subdivision of the Cenozoic Niger Delta section into three formations is insufficient for optimum stratigraphic application" Haach et al (2000) have noted that the success of future exploration will depend on linking the geology of the shelf and onshore areas to deep-water areas and exploiting new play types in older producing areas.

Despite Reijer's urgent call in 2011 for an elucidation of this new Stratigraphy, this Author has no indication of any overt moves (either by the IOCs or the NNPC) in that direction. However, there is work to do. And the significance of it makes it both imperative and urgent. As another old saying puts it, **"SOMEBODY HAS TO DO IT!"**

To my mind, that "Somebody"is the Earth Sciences and Environment Section of the Academy which might want to (**in fact, should**) throw its hat into the ring and lead the process of elucidating this new lithostratigraphy of the Niger Delta.

My suggestion comes at a time when an indefatigable Earth Scientist and PTDF Distinguished Chair of Petroleum Geology, Professor Mosto Onuoha, is about to mount the saddle of the Presidency of the Academy. Knowing the mettle of the President Elect, all one can say is,

"IT IS YOUR FIGHT, SIR!" There is nothing more to add**.**

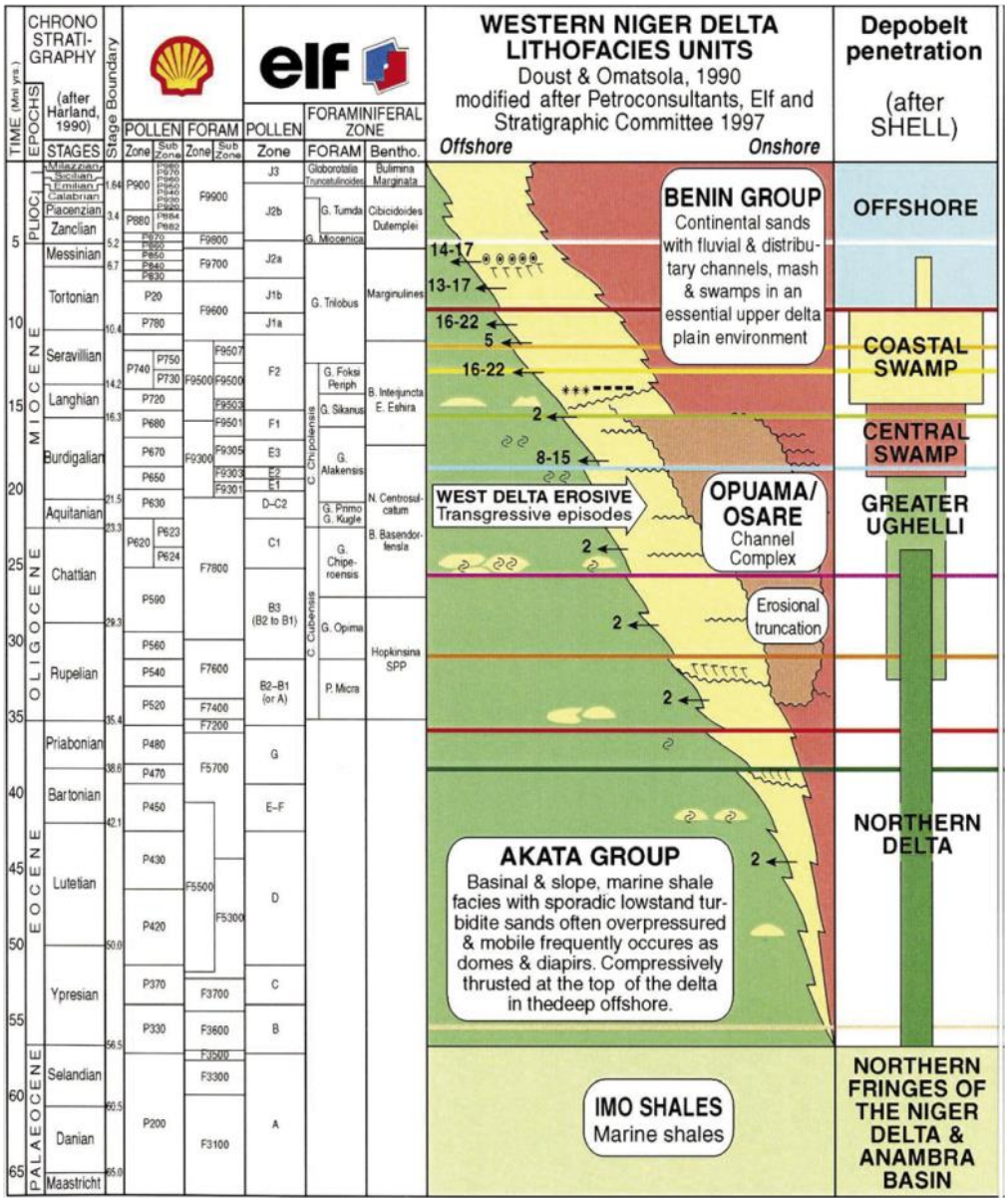

WESTERN NIGER DELTA LITHOFACIES UNITS
Doust & Omatsola, 1990
modified after Petroconsultants, Elf and Stratigraphic Committee 1997
Offshore
Onshore
Depobelt penetration
(after SHELL)
CHRONO STRATI-GRAPHY
(after Harland, 1990)
TIME (Mni yrs.)
EPOCHS
STAGES
Stage Boundary
POLLEN
FORAM
Zone
Sub Zone
FORAMINIFERAL ZONE
Bentho.
BENIN GROUP
Continental sands with fluvial & distributary channels, mash & swamps in an essential upper delta plain environment
OFFSHORE
COASTAL SWAMP
CENTRAL SWAMP
GREATER UGHELLI
14-17
13-17
16-22
5
16-22
2
8-15
WEST DELTA EROSIVE
Transgressive episodes
OPUAMA/ OSARE
Channel Complex
Erosional truncation
NORTHERN DELTA
AKATA GROUP
Basinal & slope, marine shale facies with sporadic lowstand turbidite sands often overpressured & mobile frequently occures as domes & diapirs. Compressively thrusted at the top of the delta in thedeep offshore.
IMO SHALES
Marine shales
NORTHERN FRINGES OF THE NIGER DELTA & ANAMBRA BASIN
Pliocene
Miocene
Oligocene
Eocene
Palaeocene
Messinian
Tortonian
Seravillian
Langhian
Burdigalian
Aquitanian
Chattian
Rupelian
Priabonian
Bartonian
Lutetian
Ypresian
Selandian
Danian
Maastricht
Globorotalia Truncatulinoides
G. Tumida
G. Miocenica
G. Trilobus
G. Foksi Periph
G. Sikanus
G. Alakensis
G. Primo G. Kugle
G. Chipe-roensis
G. Opima
P. Micra
C. Chipolensis
C. Cubensis
Bulimina Marginata
Cibicidoides Dutemplei
Marginulines
B. Intejuncta E. Eshira
N. Centrosul-catum
B. Basendor-fensis
Hopkinsina SPP

FIG 14.

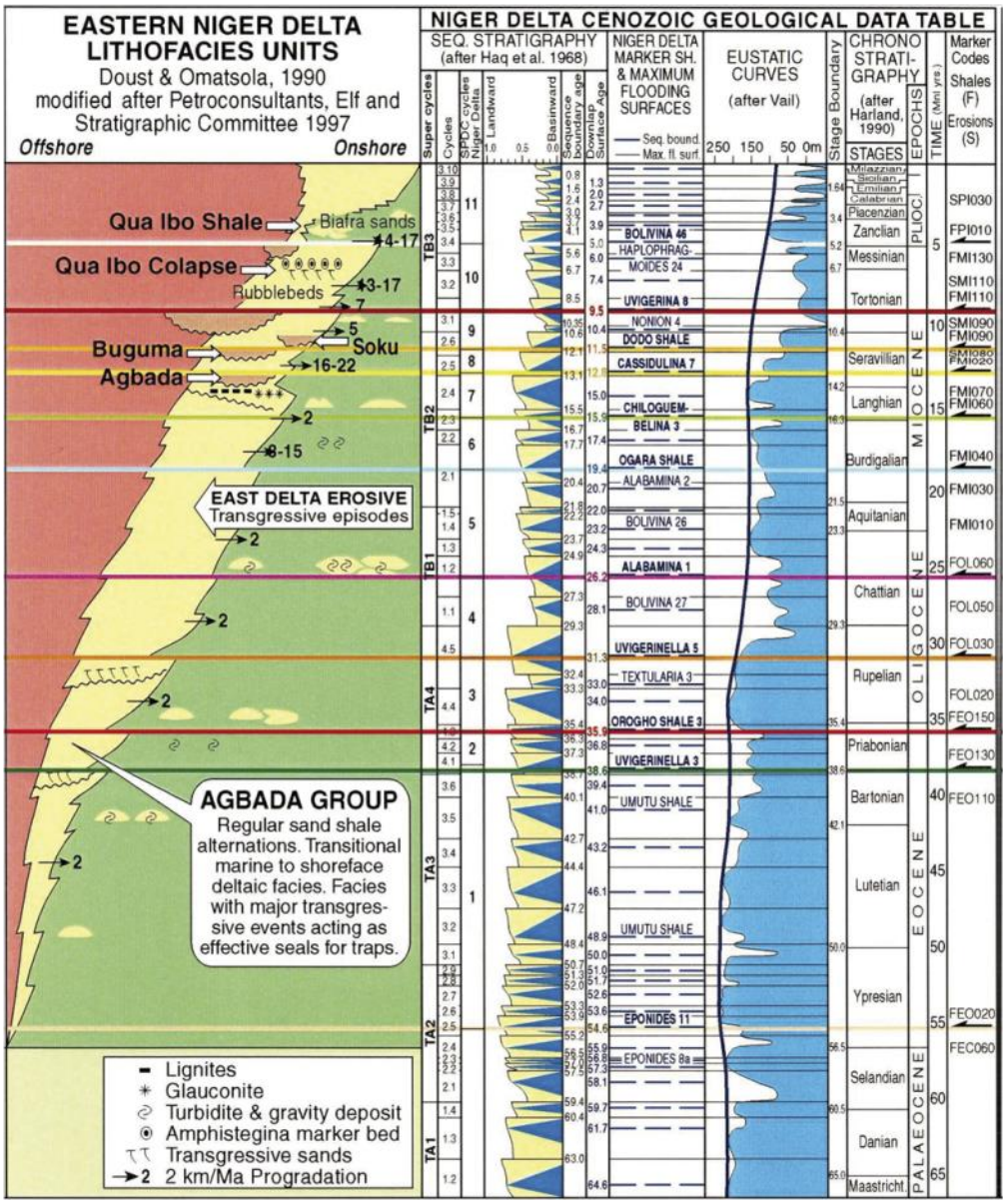


FIG 15.

Indeed, one would hope that he would seize the moment. The spoils of "war" for the country'sfortunes are too enticing to ignore! The President Elect is privileged to have in his corner, two globally celebrated Generals of Geology, Emeritus Prof Sylvester Adegoke FAS and Prof Sunny Peters FAS, who have done more than any others that I know, to bring clarity to the quest for the elucidation of the Stratigraphy of Nigeria in general and the Niger Delta in particular (see for example, Adegoke et al 1976; Petters,1982, 1983a, 1984; 1995).

EPILOGUE

DIVERSIFICATION, WHICH DIVERSIFICATION?

Mr President, Nigeria must navigate to a safe operating space from which to drive robust socio-economic growth. The calls for diversification away from dependence on petroleum should in fact start with a craving for diversification within the petroleum industry itself; a diversification from exportation of crude oil to the several economic uses to which petroleum can be put – Refining, Petrochemicals, Manufacturing,etc.

If this is done, the present daily production of 2.4 million bbls of crude oil would be gobbled up by domestic consumption leaving little or nothing for the export market. It makes it imperative that new reserves of petroleum be established and put to production or primed to go into production. In this quest, let us not be distracted neither by doom sayers who will readily point to the seeming oil glut and the plummeting prices of crude oil, nor, for that matter, by the sometimes vociferous campaigns of fringe environmentalists to, "keep the oil in the ground".

Lessons must be drawn from a similar situation in the solid minerals industry in the early and mid-1980's when prices of minerals and metals were depressed. At that time, the fast developing Asian countries kept an expanding demand for mineral raw materials which assured mineral producers of ready and growing markets for their products. These countries were advised by International Finance and Development Agencies to look away from mining and redirect their squeezed financial resources to healthier sectors. The soothsayers predicted a decline in the rate of growth in intensity of raw material use, which led to the coining of the word, "DEMATERIALIZATION." (Ostensson, 1997). Such Asian countries (now adoringly called, "Asian Tigers"), conscious of the cyclical nature of the slump in the prices of mineral resources, balked at the advice; they knew they would need the minerals and metals to sustain their drive to industrialization and they, instead, intensified their interest in exploration and investment for additional mineral raw materials particularly in Developing Countries. As for the much discussed "Dematerialization", it never happened. Metalprices were to pick up in the late 1980s and into the 1990's and the Asian Tigers smiled their way to industrialization and employment and out of poverty to opulence.

Mr President, adversities afford Nations vantage platforms for resorting to grit, ingenuity and innovation to dig themselves out of holes that threaten to swallow them. Our situation must not be allowed to be different.

NOW IS THE TIME FOR RETHINKING OUR OIL EXPLORATION STRATEGIES TO BOOST OUR PETROLEUM RESERVESTO MEET HIGHER PRODUCTION TARGETS.

In Wole Soyinka's **"A dance of the Forests",** the "Dirge Man," in emphasizing the transcendental union between the Dead, the Living and the Unborn in African mythology urges the Living (through AGBEROKO) to **"leave the dead some room to dance," to** assure a more prosperous future for mother Nigeria (Africa, if u will!).

For obvious reasons, I would rather be the "Town Crier" than the "Dirge Man." However, the message is much the same. For I see a similar transcendental link between our Sorcerers

who hold the key to further unlocking the petroleum reserves from our Source rocks, to a flourishing economy in Nigeria that such additional petroleum reserves would underpin. There are great reasons to be optimistic about the prospects of a national economic development that integrates a diversified petroleum industry.

Therefore, I say, "**leave the Sorcerers some room to dance."**

Before concluding this lecture, I would like to recall the earlier statement that there are three petroleum systems in the Niger Delta. Presently, all petroleum production comes from the Tertiary Niger Delta system. The other two, namely, Lower Cretaceous (lacustrine) and Upper Cretaceous-Lower Paleocene (marine) petroleum systems of the Niger Delta (Haack, 2000) are yet unexplored and untapped but are known from correlation of production wells in Gabon and Congo as having immense prospects (Haach, 2000).

In addition, there are the great petroleum potentialities afforded by the Anambra Basin, the Benue Trough, the Bida Basin and, yes, the Borno- Chad Basin, to name but the more obvious provinces **(see fig 16).**

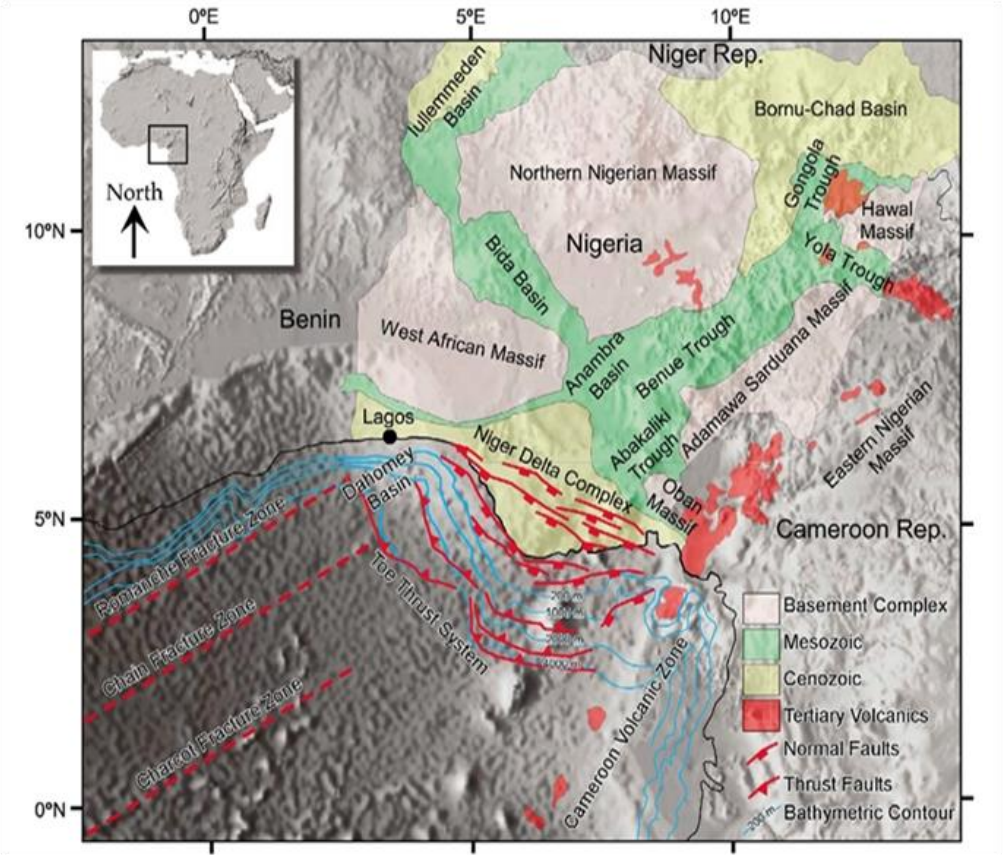


Fig. 16: Major Sedimentary basins and tectonic features of Nigeria in relation to the Niger Delta (Corredor et al., 2005).

In August, 1987, I was the Guest Lecturer for the Nigerian Association of Petroleum Explorationists (NAPE) at a Public Interaction in the Ball Room of the Eko Hotel, Victoria Island, Lagos. **My keynote Address was entitled "Source Rocks and Sorcerers (Really?).** On that occasion, I adduced geological evidence to show that the aforenamed basins are oil bearing. Today, the Anambra Basin has been drilled and petroleum reserves have been established. I also asserted that much of the Dahomey Basin covering the areas of our African neighbours to the west and east are oil bearing. Some oil professionals in the audience murmured their disbelief. Currently, petroleum is being exploited in almost all, perhaps all, of these countries. Those who were at that NAPE Meeting in 1987 still call me "**Sorcerer!"**

In my Keynote Address in March, 2015 titled, **" Mineral Exploration in Offshore Nigeria and the Blue Economy,"** to the 51st Annual Conference and Exhibitions of the Nigerian Mining and Geosciences Society (NMGS), coincidentally in the same Ball Room(now, more ornately decorated), as my 1987 NAPE Speech, I traced how the paroxysms of rage, fire and brimstone that separated the African and South American Continents, left Nigeria with an embarrassment of riches including vast deposits of petroleum in the intervening waters within our Exclusive Economic Zone(EEZ). The gasps in the room were palpable!

When, therefore, I hear folks talk glibly about Nigeria's oil running out, I often say a little prayer for them, "Lord, forgive them for they know not what they say!"

If I am allowed a parody of an infamous declaration by a Nigerian Ruler (spare him the blushes, so no names!) in the mid 1970's, "Our problem is not the availability of oil but how to use it!"

For the avoidance of doubt, I am aware that in the 1980s into the 1990s, the Nigerian Government through the NNPC had expressed ambitions, and actually took baby steps, towards increasing our petroleum reserves to 30 billion bbls by 2003 and to 40 billion bbls by 2010. When last I checked, we were way behind in meeting even those modest targets. We need to do much more!

Mr President, our collective responsibility as a Nation is, "to put our house in order," to enable us take great economic advantage of our copious Source Rocks and the petroleum reservoirs that they have fed over geologic time. In this regard, our ebullient Sorcerers, the foremost of who are ensconced in the Academy and at UNIPORT (among other Temples of learning and Enterprise), can't wait to bring their skills to the Table!
The more source rock knowledge is deployed particularly in the context of petroleum systems, the more innovations for their use will be established and the greater the potential for unearthing new hydrocarbon deposits with consequent improvements in efficiency and proven reserves especially in the tantalizing new petroliferous provinces including the prodigious offshore region.

No matter in what directions we choose to go in our overall diversification drive, the need is urgent to look within the Petroleum Industry with a view to diversifying it and building necessary buffers in our petroleum production. A stable and prosperous economic future for Nigeria may well depend on it.

The Nigerian Academy of Science has a pressing obligation to awaken national consciousness towards this objective by facilitating the imperative love tango between the Nation's Sorcerers and Her Source Rocks!

In this context, **"LEAVE THE SORCERERS SOME ROOM TO DANCE"** becomes a compulsion rather than a convenience.

God bless you all for coming.

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AN INTERVENTIONAL STRATEGY FOR ADDRESSING THE SOCIAL DEVELOPMENT AND REPRODUCTIVE HEALTH NEEDS OF THE YOUTH IN NIGERIA; LESSONS LEARNT

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Abstract

The youth constitute a critical age group especially in a populous nation like Nigeria. Therefore, a lot more needs to be done to address the needs (social development and reproductive health) of the youth. The Nigerian Academy of Science set up a project to address the needs of youth by working with the youth and various stakeholders, including two state governments, to identify and develop evidence-based policy to respond to the needs. The needs assessment involved data collection from the youth and other stakeholders and the collective review of the findings. Consequently, strategic plans were developed for each state. Diverse strategies were employed which promoted partnership among the stakeholders and led to ownership of the policy documents (strategic plans) developed.

Keywords: Youth, policy, evidence-based policymaking, intervention, strategy, Nigeria.

Introduction

The youth are a much talked about group though the definition of youth is often varied depending on diverse factors including social, economic, and cultural factors, among others. According to the United Nations Department of Economic and Social Affairs, youth being a period of transition from the dependence of childhood to the independence of adulthood, explains the fluidity of that category compared to other age-groups (UNDESA, 2014). United Nations entities and regional organizations have somewhat different definitions but all put youth as those somewhere between the ages of 15 and 35 years. The World Health Organization defines youth as being between 10 and 24 years (UNDESA, 2014).

Globally, young people (aged 10 to 24 years) are about 1.8 billion, and more than 90% of them live in less developed countries (UNFPA, 2014). Africa is the most youthful continent with more than a third of the population being between 10 and 24 years while Nigeria is the most populous nation in Africa (UNFPA and PRB, 2012; NPC and ICF, 2013). In Nigeria, the youth are estimated to be 80 million, representing 60% of the population. (Okafor EE, 2014).

Youth comprises a critical period of vulnerability due to the physiological and sociological changes taking place. Not only so, but the youth form a critical mass in the population structure of the society. They form a significant part of the workforce required for national development apart from constituting a significant fraction of the general population itself. It is now thought that sustainable national socio-economic development is only achievable with youth development (UNFPA, 2014).

However, the youth today are in a world that is far more complex than what it used to be and, consequently, are challenged in ways only imagined decades ago (Fatusi and Hindin, 2010). Globalization, technological advancements, political changes, migration, and economic challenges all pose serious challenges to the development of the youth, especially in developing countries. To measure up and be able to meet the productivity demands of the current age will take deliberate and concerted effort by the youth themselves and their governments.

The issues affecting the youth in Nigeria, and indeed globally, are many and relate to all aspects of life, be it developmental, economic, sociological, etc. They also include reproductive health challenges such as early sexual initiation, early marriage and unsafe sexual practices, among others, with the consequences of increasing rate of unwanted pregnancies, unsafe abortions, and sexually transmitted infections (STIs), including HIV and AIDS (Denno, Hoopes, and Chandra-Mouli, 2015; Bernat and Resnick, 2006). When the social development needs of the youth are not met, it is revealed in unemployment, restiveness, high crime rate, low literacy, lack of access to health care and non-involvement in decision making on national issues.

To respond to the challenges of young people's health and development, the governments in Nigeria (at federal and state levels) have drafted various policies and also set up ministries of youth to serve as focal ministries to adequately address the challenges facing the youth. The Child Rights Act has also been passed in at least 23 states of the federation. Despite these laudable acts, there seems to be a lack of a systematic and collaborative approach to dealing with the issues of the youth.

It has been suggested that, in order to effectively address the problems of the youth, strategies that promote collaboration among various partners should be utilized (Barton, Watkins, and Jarjoura, 1997). All stakeholders have to partner to develop the necessary policies as well implement them.

However, making effective policies in Nigeria is problematic for many reasons. There is a critical gap of translating research evidence into appropriate policies. Oftentimes, policies have been enacted without an adequate evidence-base leading to ineffective policies that fail to be implemented and, indeed, cannot be implemented. Policymakers have to develop a culture of evidence-based policymaking. Also, policies are developed without input from critical stakeholders. Many previous efforts at effective policymaking in Nigeria have focused more on developing the capacity of the policymakers to appreciate evidence and the use of same for policymaking and not particularly on strategies that promote collaboration among key stakeholders towards the development of policies (Uneke, Ezeoka, and Ndukwe, 2011; Uneke, Aulakh, Ndukwe, and Onwe, 2012).

The Nigerian Academy of Science (NAS) had also explored ways of influencing evidence-based health policies by enhancing the capacity of policymakers to use evidence (Hawkes et al. 2015). For the current effort at addressing youth development, the evidence to policy gap is bridged by working with the youth and key stakeholders in two states in Nigeria to develop strategic plans of action. The aim of the project was to help two state governments come to a realization of the challenges facing the youth in their localities, think through what needs to be done, and work with the stakeholders in their states to address the social wellbeing and reproductive health of the youth.

This paper summarises the strategy used for the development of appropriate policies (strategic plans) to address the social reproductive health of the youth in two Nigerian states with a focus to highlight lessons learnt.

Goal and Objectives of Project

The goal of the intervention project was to mainstream the promotion of life skills, livelihood, and social development of youth into the broader development agenda at all levels in Nigeria.

The specific objectives of the project were as follows:

1) To build partnerships and collaboration for understanding the social development and reproductive health needs of youth aged 10-24 years in Nassarawa and Ekiti States of Nigeria;
2) To develop a strategic plan of action for improving the social development and reproductive health of the youth in partnership with policymakers and official gatekeepers in the two states using the results of the needs assessment; and
3) To mobilize top level political leadership and relevant multi-stakeholders in both states to accept the plan and to commit resources to implementing it and sustaining it over time.

Strategies for implementing the project
Intervention Sites

The states were purposively selected based on their reputation for purpose-driven governance as well as the relative ease of access to their governments at the highest level, given the clout of the members of the Nigerian Academy of Science within the states.

Ekiti State is located in the south-western geo-political zone of Nigeria. The 2006 national census (the last one conducted till date) put the population of the state at 2,384,212. On the other hand, Nasarawa State is located in the north-central geo-political zone of Nigeria. The state is bordered on the west by the Federal Capital Territory (FCT), Abuja. According to the 2006 population figures, the population of the state is 1,863,275.

The project was carried out in two main phases in both states. The first phase was a needs assessment study with the objective of determining the needs of the youth in the states, present the report to the relevant stakeholders, and obtain their commitment to address the needs by committing to a process of drafting appropriate strategic plans.

The second phase was the inclusive development of state-specific strategic plans that address the needs identified (in phase one above) and adoption of the same by the states. It was important that the strategy used to develop the strategic plans encouraged collaborative partnership among the stakeholders to achieve ownership of the plans developed.

Conducting a Needs Assessment Study

There were advocacy visits to the executive council and legislature of each state at the start of the project. The visits were led by the President of the Nigerian Academy of Science to secure the consent of the highest political leaders in the states. Then, field study teams were competitively selected to conduct needs assessment studies using various data collection tools including questionnaires, observational checklists, as well as focus group discussion

and interview guidelines. The studies were conducted between October and December 2013.

Subsequently, a meeting of key stakeholders (including the youth) was held where the findings of the needs assessment study were presented and discussed before the report of the study was finalised for publishing.
Ethical approval for the needs assessment study was received from the Nasarawa State Ministry of Health. With the approval of the Ekiti State government, ethical clearance for the study was received from the Oyo State Ministry of Health Ethics Review Committee (as Ekiti State had no approved Ethics Review Committee at the time).

Development of Strategic Plans

At the meetings to discuss the findings of the needs assessment studies, the stakeholders constituted two multi-stakeholder committees towards the drafting of strategic plans for their states. The Political Committee, consisting of high level political office holders, was for advocacy and helped to facilitate interactions with stakeholders (especially government) within the state. The second was the Technical Committee with the responsibility of drafting the strategic plan.

Specifically, in Nasarawa State, the Political Committee consisted of the Commissioners of Finance, Health, Youth and Sports, Women Affairs and Social Development, and Education, Science and Technology, as well as the Chairman of the Committee on Youth and Sports at the Legislature. The Technical Committee had 20 members drawn from the government ministries, schools, and youth related non-governmental organisations.

The Political Committee in Ekiti State had 14 members including Commissioners and Permanent Secretaries of related ministries as well as a Special Adviser to the Governor and two senior legislators (the Majority Leader and the Chair of the Health Committee). The Technical Committee had 25 members with a similar composition as in Nasarawa, but with representatives from the job creation agency and skills acquisition centres in the state.

In all, there were two strategic planning sessions held in each state in June and July 2014. The sessions in Ekiti were hosted by the Ministry of Health while the Ministry of Finance hosted the meetings in Nasarawa.

Ownership and Adoption of Strategic Plans

The process of building ownership and adoption of the strategic plans in the states started with the advocacy visits by the Academy at the commencement of the project. Further advocacy visits were made by the field study teams and the staff of the Academy at intermittent periods throughout the project.

The youth and other stakeholders were involved in the project from its beginning, having completed questionnaires and participated in interviews and focus group discussions. Additionally, meetings were held with the stakeholders within each state following the collection and analysis of needs assessment data in the state. The drafting of the strategic plans involved representatives of the various stakeholders.

Outcome of intervention project

The project set out to build partnerships and collaboration for understanding the social development and health needs of the youth, and develop a strategic plan that would be owned and accepted by the stakeholders in the state. The strategy employed to achieve this is described below.

Partnership for Understanding the Needs of the Youth

The needs assessment reports of the studies conducted were well received and adopted by the states. Following the advocacy visit by the Academy leadership to the executive councils and legislature of each state, the field study teams paid additional advocacy visits to stakeholders (having received official letters of introduction from the Academy) before commencing the needs assessment studies. Intermittently, during the program, staff of the Academy liaised with government officials and other stakeholders (through site visits, telephone, and email communication) to ensure their continued support and involvement in the process.

The selection of study teams had to be carefully done. It was important to select teams with the capacity as well as local knowledge (especially given that the needs assessment study would request sensitive information on reproductive health) to conduct the studies. It was important that the teams inspired collaboration among the different stakeholders. Teams were recruited only following interviews by the Academy's project team.

Data collection tools were developed collectively among the study teams to enable comparison of the findings in the two states as may be necessary. Two joint meetings were held to develop and harmonise the tools. The tools were then tested on the field and adapted, to ensure appropriateness for the stakeholders, before being deployed for the needs assessment studies.

In order to ensure the participation of the youth, needs assessment studies were planned with consideration for the school calendar. Given the challenge of program timeline (as agreed with the funder), data collection was timed to coincide with the end of examinations but before school closure for holidays. In all, 633 in-school and out-of-school youth participated.

To promote partnership, among the various stakeholders, for understanding the social development and reproductive health needs of the youth in each state, the stakeholders participated in the needs assessment study. Also, closed door meetings were held with the youth and other stakeholders present to discuss the findings of the studies and to agree on plans of action for developing strategic plans that address the needs identified.

The project held at a time of political instability and violence in both states. There were governorship elections held in both states during the period of the program in the states, and such is often marked by instability and even violence in the country. Teams travelling in and out of the states had to be aware of the security implications at each period and conducted their visits accordingly. In addition, the needs assessment findings had to be presented during closed-door meetings (with the exclusion of media representatives) to avoid the studies being used as instruments during the political campaigns.

Having presented the needs assessment reports to the stakeholders, it was necessary to ensure that the strategic plans to be developed would be accepted by the top level political leadership and other stakeholders. This was achieved by ensuring that the stakeholders present during the presentation of the findings of the needs assessment study immediately

constituted two committees (in each state) towards the development of the strategic plans. Both committees were chaired by senior government officials.

The first committee (the Political Committee) constituted towards the development of the strategic plans was for advocacy and, consequently, had senior policymakers as members. The committee facilitated interactions with government at any level required and ensured the hosting of the strategic planning meetings at venues provided by government ministries.

The second committee (the Technical Committee) consisted of the youth, senior and middle level government officials, and other stakeholders. The committee held two strategic planning sessions (in each state) to analyse, discuss, and agree on the contents of the plan. The meetings were facilitated by the academy's study teams, which also wrote the draft plans. The draft strategic plans were subsequently shared with various stakeholders and senior government officials for their input before being finalised for publishing.

Political Acceptance and Ownership of Strategic Plans

The strategic plans, having been developed inclusively by relevant stakeholders in the state, were launched by the governors of the states at events that were well publicised. Attendance at these events were by all relevant stakeholders including the youth, civil society groups, government officials, and the media. Policy statements indicating their adoption of the reports and support for implementation were made by the governors and other policymakers at the events. Other stakeholders also expressed their support for the implementation of the plans.

Forewords to the strategic plan reports were written by the most senior government officials of some of the ministries (ministries of youth, education, women affairs, science and technology, and health) involved in both states. Having obtained the necessary permission, the plans were also branded with the insignias of the respective state governments. These were important to demonstrate ownership and adoption of the plans by the governments.

The change in political leadership in Ekiti State, following governorship elections held, and just before the state's strategic plan was to be publicly presented necessitated a delay in the event. An advocacy visits by the Academy leadership had to be made to the Governor (and the team was received by the Deputy Governor) to intimate him about the project and the need to ensure continuity. The strategic plan developed was presented and the governor's review requested. With the consent of the new government in Ekiti, a date was agreed when the public presentation of the plan was done.

Facilitating the commitment of state resources to the implementation of the strategic plans was the reason for the inclusion of representatives of the ministries of finance and the legislature in the program from the beginning. In fact, the chairman of the Political Committee in Nasarawa was the Commissioner of Finance and the strategic planning sessions in the state were held in the conference room of that ministry.

Media Presentation of Strategic Plans

The academy organised a presentation of the strategic plans to representatives of various media agencies (covering television, radio, and newspaper organizations) to ensure wide publicity and indirectly stimulate political will and commitment. Various media representatives were invited to the event where a brief presentation of the process of development and the key contents of the plans were made. This was followed by a robust discussion session which allowed the media representatives to clarify issues. Copies of the plans were then given to them. The involvement of the media was also to ensure that the strategic plans were well publicised and many more stakeholders would be aware of their existence. Ultimately, this would help to ensure that the governments kept youth development and the implementation of the plans on their agenda for development in their states.

Lessons Learnt

Several lessons were learnt in the course of implementing the intervention studies in the two states. Some of the key lessons are with respect to the development of program timelines, the importance of advocacy in influencing evidence-based policymaking, the need to ensure a process that engenders ownership of projects by stakeholders, and the need to work with all categories of government officials (employees/decision makers) and not elected officials (political office holders) alone in implementing such programs. Various

Flexibility in Program Design

Given the unpredictable nature of the socio-political environment, there is a need to design programs with some flexibility in-built. There were some occurrences of violence in both states during the period of the program that necessitated variations in timing of activities and visits. There were also sudden cancellation of appointments given by the state officials due to the prevailing circumstances and, sometimes, unexplained reasons. Without a degree of flexibility being built into the programmatic timeline to accommodate some of these changes, the project would have failed.

Importance of Advocacy

The project would not have been a success without the use of advocacy. It was particularly important to have paid advocacy visits to the top level government officials. Visits made to the governors and their respective executive councils at the inception of the project facilitated access to the government ministries and schools in implementing the project. Necessary access to records was made easy by the prior advocacy visits. The project was at risk of being abandoned in Ekiti following the change of governors in the state. Delaying the publishing of the report till after an advocacy visit was made to the new government helped to keep the project on track by securing the buy-in of the new government.

Involvement of Career Civil Servants and not just Political Office Holders

The involvement of the career civil servants and not just elected policymakers aided continuity of the project in Ekiti. Oftentimes, emphasis is put on the need to engage the highest level of policymakers in influencing policymaking for the youth, especially as they are often much older and belong to another generation. These high level policymakers are usually elected into office and so may leave before the desired policies can be enacted or

implemented. As it occurred in Ekiti State, the senior career government officials at the ministries, helped to ensure continuity of the program having been involved from the beginning. These officials were able to brief the new government of the existing program and advise on the need for continuity.

Importance of Ownership

Policies are written up many times that are never accepted by the relevant stakeholders. Uzo. To ensure that these strategic plans to address the social development and reproductive health needs of the youth were well accepted by all stakeholders in both states steps to engender ownership had to be implemented at various stages of the development of the plans.

Various stakeholders participated in the data collection, completing questionnaires, or being interviewed or participated in focus group discussions. Also, all the stakeholders attended the meeting to discuss the findings of the needs assessment study. All were also represented in the committees that developed the strategic plans. Obasanjo and Oduwole (ND), in analysing how HIV/AIDS programs and policies is influenced in Nigeria pointed out the important role of a participatory approach and even involving the stakeholders in research.

The advocacy visits to the top level political leadership, involvement of government and other stakeholders in the development of the plans, and the public presentation of the plans by these political leaders eased acceptance by all stakeholders.

Conclusion

The project set out to promote collaboration among stakeholders to address the social and development needs of the youth. The participatory approach employed in the conduct of a needs assessment and strategic plan development in Nasarawa and Ekiti States resulted in the launching of policy documents that were acceptable to the youth and the other stakeholders in the states.

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Conflict of interest

None declared.

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"THE BATTLE AGAINST TRANSBOUNDARY

ANIMAL DISEASES IN NIGERIA

AND SOME WEST AFRICAN COUNTRIES"

by

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INTRODUCTION

The President of the Nigerian Academy of Science, the Chairman of the occasion, distinguished Fellows of the Academy, our Fellows for today's induction, invited guests, gentlemen of the press and media, ladies and gentlemen.

It gives me great pleasure to have been chosen to give this lecture. I have chosen this title because in recent years some animal diseases have become increasingly important in terms of their economic or zoonotic impact in Nigeria as well as its neighboring countries.

TRANSBOUNDARY ANIMAL DISEASES

Transboundary Animal Diseases (TADs) are defined by Food and Agriculture Organization Emergency Prevention System (FAO/EMPRES) as those animal diseases that are of significant economic, trade, and/or food security importance for a considerable number of countries; and which can easily spread to other countries and reach epidemic proportions and where control/management, including exclusion, requires co-operation between several countries. The occurrence of any of these diseases in any country may compromise food security through serious loss of animal protein and/or loss of draught animal power for cropping, may lead to significant production losses in meat, milk, and other livestock products.

It may also make it impossible to up-grade the production capacity of indigenous livestock importation breeds through high-producing exotic breeds which are usually highly susceptible to these diseases. The prohibitive cost of control of these diseases increases, very significantly, production costs while TADS in a country may disrupt or inhibit trade in livestock and livestock products and, in effect, adversely affect national export economy. Some transboundary animal diseases such as Highly Pathogenic Avian Influenza (HPAI) or Rift Valley fever are transmissible to humans (zoonosis) and therefore have public health consequences of varying magnitude. Others like Rinderpest may lead to decimation of wildlife population and therefore have environmental impact as well as adversely affect tourism and recreational opportunities for individual countries.

In Nigeria, with the global eradication of Rinderpest, the most important TADS that may have serious negative impacts on our food security are Peste des Petits Ruminants (PPR), African Swine Fever (ASF), Highly Pathogenic Avian Influenza, Newcastle Disease (ND) of poultry, and Contagious Bovine Plueropneumonia (CBPP). Other TADs that are prevalent but with less dramatic effects on our national food security include Foot and mouth disease (FMD), Lumpy Skin Disease (LSD), and Sheep and Goat Pox.

Rinderpest is a highly infectious viral disease of cattle, buffaloes, and some wildlife characterized by fever, necrosis of the oral cavity and alimentary canal, severe diarrhoea, and death in up to 90% of a susceptible herd. The disease entered Nigeria in 1886 through Chad killing 80-90% of the Fulani cattle. The 1983-85 outbreaks in Nigeria according to Nawathe and Lamorde (1985) caused a few Fulani herdsmen to commit suicide while others gave up their traditional profession of cattle tending. The first internationally co-ordinated control programme in West Africa between 1962 and 1969 (Obi 1993) cost an estimated $16.4 million while a latter programme, the Pan African Rinderpest Campaign (PARC) involved 24 countries and about 65,000 personnel and technicians.

Peste des petits ruminants is a severe fast-spreading disease of domesticated and some wild small ruminants characterized by sudden onset of depression, fever, discharges from the nose and eyes, sores in the mouth, disturbed breathing, diarrhoea, and death.

The disease was first reported in Cote d'Ivoire in 1942 (Gargadenec and Lalane 1942) who because it resembled rinderpest (Peste bovine; bovine plague) gave it the name Peste des Petits Ruminants (Small ruminant Plague). In subsequent years, the disease came to be recognized in Benin Republic, Senegal, Nigeria, Ghana and, eventually, in most countries of West Africa. It is now known that the disease is widespread in countries of sub-Saharan Africa including Ethiopia and Sudan, as well as in Saudi Arabia, Oman, United Arab Emirates, Lebanon, Israel, Kuwait, Jordan, Iran, Yemen, Turkey, and Iraq. Outbreaks of PPR are now known to be common in India, Pakistan, Nepal, Bangladesh, and Afghanistan. It has been speculated that the recent increased geographical distribution of the disease derives from improved methods of laboratory diagnosis as well as increased awareness since it is obvious that PPR had for many years been confused with other diseases which present similar clinical and pathological features as PPR.

African Swine Fever (ASF) is a highly contagious viral disease of domestic pigs characterized by fever, hyperemia of the skin, incoordination, diarrhoea, and pneumonia. It may cause high morbidity and high mortality and is a serious transboundary animal disease with the potential for rapid international spread.

First described by Montgomery in 1921 in Kenya, ASF has subsequently been reported in most countries in southern and eastern Africa, where the virus is maintained either in a sylvatic cycle between warthogs (Phacochoerus aethiopicus) and ticks of the Ornithodoros moubata complex or in a domestic cycle that involves pigs of local breeds, with or without tick involvement. Countries where endemicity is confined to the sylvatic cycle include Kenya, Namibia, Botswana, Zimbabwe and northern South Africa. A cycle in domestic pigs apparently occurs in Angola, the Democratic Republic of the Congo, Uganda, Zambia, Malawi, northern Mozambique and probably the Congo (Brazzaville), Rwanda, Burundi and Tanzania. Madagascar experienced ASF for the first time in 1997-98; it caused serious losses and has not yet been eradicated.

In West Africa, ASF has been endemic in Cameroon since the first reported outbreaks in 1982. It is endemic in southern Senegal, the Gambia, and probably Guinea Bissau and the islands of Santiago and Mao in the Republic of Cape Verde. The disease has been present in this focus since at least 1958-60.

In Nigeria, an outbreak of ASF occurred in 1973 in a piggery in Abeokuta, Ogun State where all the 3000 pigs in the farm died from the disease. In October 1997, ASF was reported in Benin, rapidly followed by Togo and in September 1997 the disease surfaced in free-ranging pigs in four local government areas of Ogun state, of Nigeria that have common borders with Benin Republic. The disease was first seen in villages alongside the lagoon, passing into Nigeria from Benin Republic. Dead pig carcasses were seen in the lagoon and there was evidence that boats were traveling along the lagoon selling pig meat in Badagry market and nearby villages. By December 1997 ASF was reported in Badagry in Lagos State, Nigeria and from the Lagos and Ogun state foci, the disease eventually spread to Osun, Oyo, Ondo, Ekiti, Edo, Delta, Anambra, Enugu, Abia, Rivers, Bayelsa, Akwa-Ibom, Cross-River, Benue, Kaduna, and Plateau states of Nigeria. By October 1998,

about 125,000 pigs had died of the disease in nine states resulting in an estimated loss of N1.0 billion. In October 1999, ASF was reported in Ghana. All of the countries in sub-Saharan Africa that have significant pig populations must be considered to be infected, potentially infected, or at risk from ASF.

Highly Pathogenic Avian Influenza (HPAI) is a viral disease affecting the digestive, nervous, and respiratory systems of all domestic and wild birds that is characterized by respiratory, reproductive, digestive and/or nervous signs with high morbidity and mortality with an incubation period of few hours to few days. It is highly contagious and infectious and may be fatal in humans. The disease affects all ages, but is more serious in the young.

Avian Influenza Viruses (AIVs) are members of the family Orthomyxoviridae and genus Influenza A. The influenza viruses that constitute this family are classified into types A, B or C based on differences between their nucleoprotein and matrix protein antigens. AIVs belong to type A. Influenza viruses are further categorized into subtypes according to the antigens of the haemagglutinin (H) and neuraminidase (N) projections on their surfaces. There are 16 haemagglutinin subtypes (H1-H16) and 9 neuraminidase subtypes (N1-N9) of influenza A virus, and AIVs viruses have representatives in all of these subtypes. Additional H17 and H18 types have been described in bats not birds. However, to date all highly pathogenic AI viruses that cause generalized rather than respiratory disease belongs to either the H5 or H7 subtypes. For example, the classical fowl plague virus is H7N7 and the virus responsible for the major epidemic in the eastern United States in 1983/84 was H5N2. However, not all H5 and H7 viruses are virulent for poultry. In 2013, Influenza A H7N9 emerged in China with low pathogenicity in birds but caused high morbidity and case fatality in humans. In Nigeria, HPAI emerged in epidemic proportions in 2006.

I will now focus on the diagnosis and control of Rinderpest, PPR, and HPAI where I played significant roles at various stages of the battles. For effective control of any of these diseases, you must have a good diagnostic technique to be able to quickly detect the disease and take measures to restrict it to the primary focus and prevent spread and take measures to control and possibly eliminate the disease. For the diagnosis of Rinderpest, the following techniques had been used: Agar gel Immunodiffusion test (AGID). (Scott and Brown 1961), Immunoperoxidase staining (Salvakumar et al (1981) (Dandio and Obi 2001), Immuno-capture Enzyme linked

Immunosorbent Assay (ELISA) (Libeau et al 1997), Reverse transcriptase Polymerase Chain Reaction (RT PCR) (Barret et al 1993), Indirect ELISA for antibody detection (Anderson et al 20016), and monoclonal antibody based Competitive ELISA (Libeau et al 1997). For both PPR and Rinderpest control, a robust, specific, and sensitive diagnostic test is imperative. In co-operation with Dr. Ken McCullough of the Institute for Animal Health (previously called The Animal Virus Research Laboratory) Pirbright, UK, we decided to immuno-engineer monoclonal antibodies by fusion of spleen cells of Balb/C mice which had been immunized with the Nigerian PPR virus (NIG. 75/1) and Kenyan Kabette Rinderpest virus. A Monoclonal Antibody (MAB) is a highly specific antibody secreted by a single cell's progeny - (Clone) usually directed against not just a protein of an antigen but indeed an epitope on the protein.

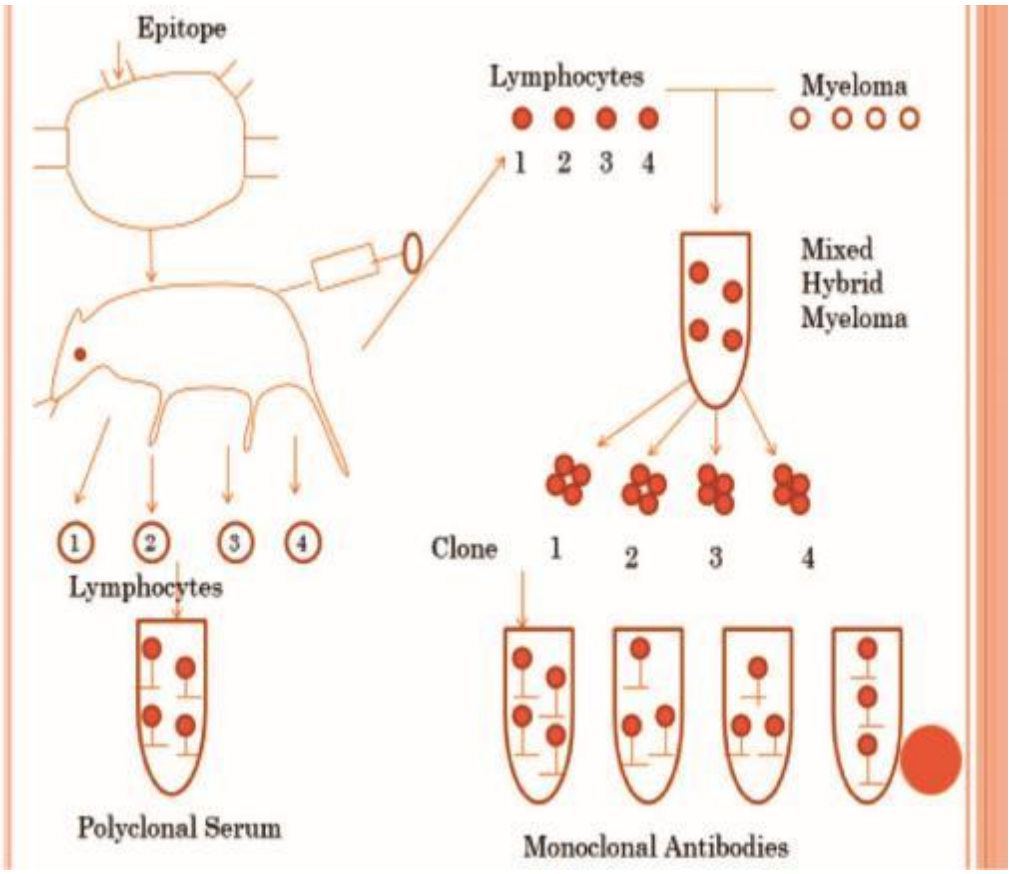

Fig. 1: Basic principles of Monoclonal Antibody Production.

We were able to produce monoclonal antibodies against the nucleocapsid (N), Matrix (M) and the Fusion (F) proteins of both viruses. Indeed I produced the first Monoclonal antibodies against the PPR virus. These MAbs were then used in both indirect and competitive ELISA to diagnose both PPR and Rinderpest. The most exciting result was the production of MAbs which were used to differentiate the two closely related diseases. The immunization of mice for MAb production may take about four weeks to three months depending on how many booster doses of the antigen one is required to give and the class of antibodies (IgG, IgM or IgA) one intends to produce. From fusion to harvesting of the antibodies may take another three months. To reduce the time required for Mab production and reduce reagent and labour costs we developed a combined fusion-cloning method in which the fusion cocktail was treated with aminopterin 24 hours after fusion followed by blind semi-solid cloning in aminopterin-free media. We therefore succeeded in reducing the Mab generating interval from above three months to about 4 weeks.

Having read from literature that successful MAb production depended on spleen cells of immunized mice that are in the blast transformation phase, I produced MAbs by fusion of splenocytes of mice that has been given a single intra-splenetic injection of the PPR virus followed in three weeks by another shot intravenously. This technique reduced the immunization time from above three months to 3 weeks.

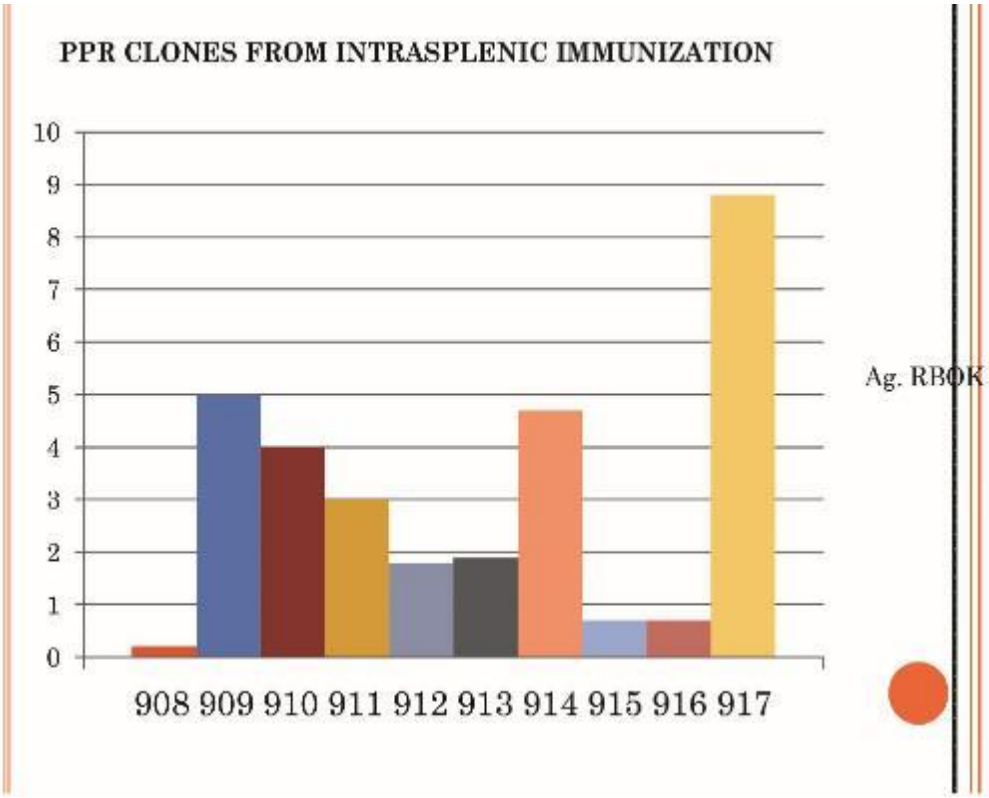

Fig 2: Reactivity of ten MAbs produced from Intra-splenic immunization of mice against Rinderpest virus (Note clones 908, 915, and 916 do not react with Rinderpest virus antigen).

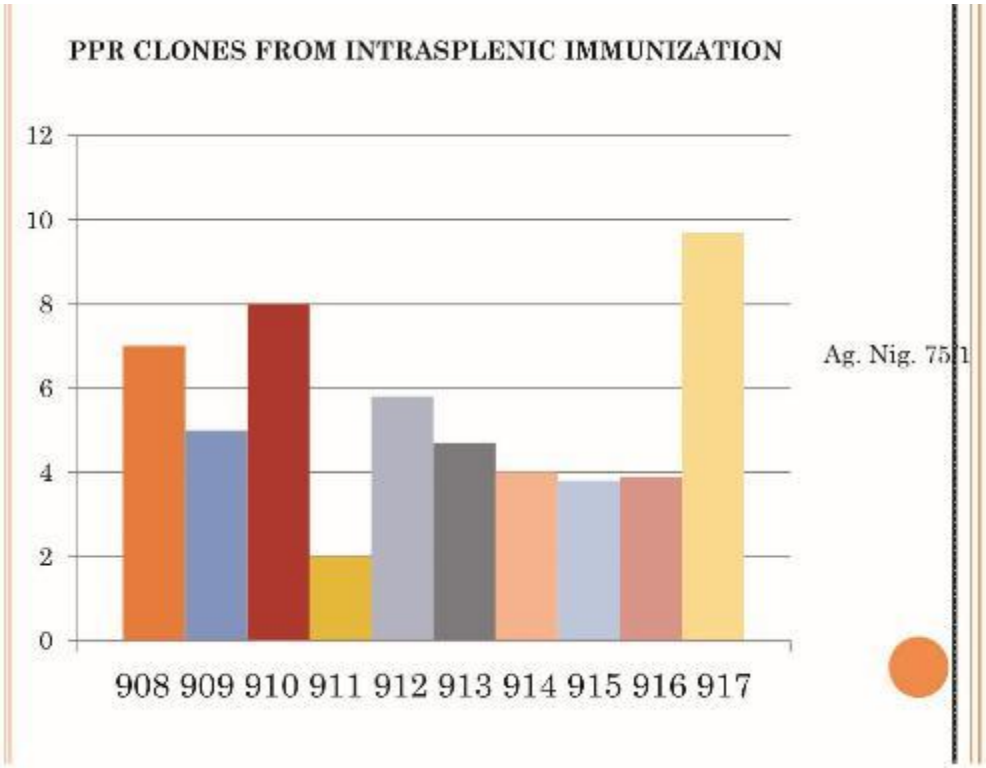

Fig 3: Reactivity of ten MAbs produced from Intra-splenic immunization of mice against PPR virus.

In competitive ELISA to assess the reactivity of our MAbs, against PPR isolates from Nigeria, Ghana, Únited Arab Emirates, Sudan, and Oman as well as Rinderpest isolates from Nigeria, Saudi Arabia, Tanzania, Oman, Egypt, Lebanon, Kuwait, and Yemen, we identified MAbs that reacted with all the PPR and Rinderpest isolates, two that reacted with rinderpest but not PPR isolates, and some that reacted with viruses from some but not other geographical areas or zones. We thus had in our hands potential reagents that would enable us say that the aetiological agent is either Rinderpest or PPR and vice-versa and another that traces back the origin of the disease to particular geographical regions.

Together with my colleagues in Ibadan and post-graduate students we were able using the PPR MAbs, to develop a DOT-ELISA whose advantages over ELISA include the facts that it uses less quantities of reagents, has shorter incubation period, better signal-noise ratio therefore resulting in less false positive results, and can be read visually without need for a spectrophotometer. In addition, we developed an

immuno-peroxidase staining of paraffin fixed and wax-embedded tissues (that had been stored for up to ten years) thus enabling retrospective diagnosis of the disease.

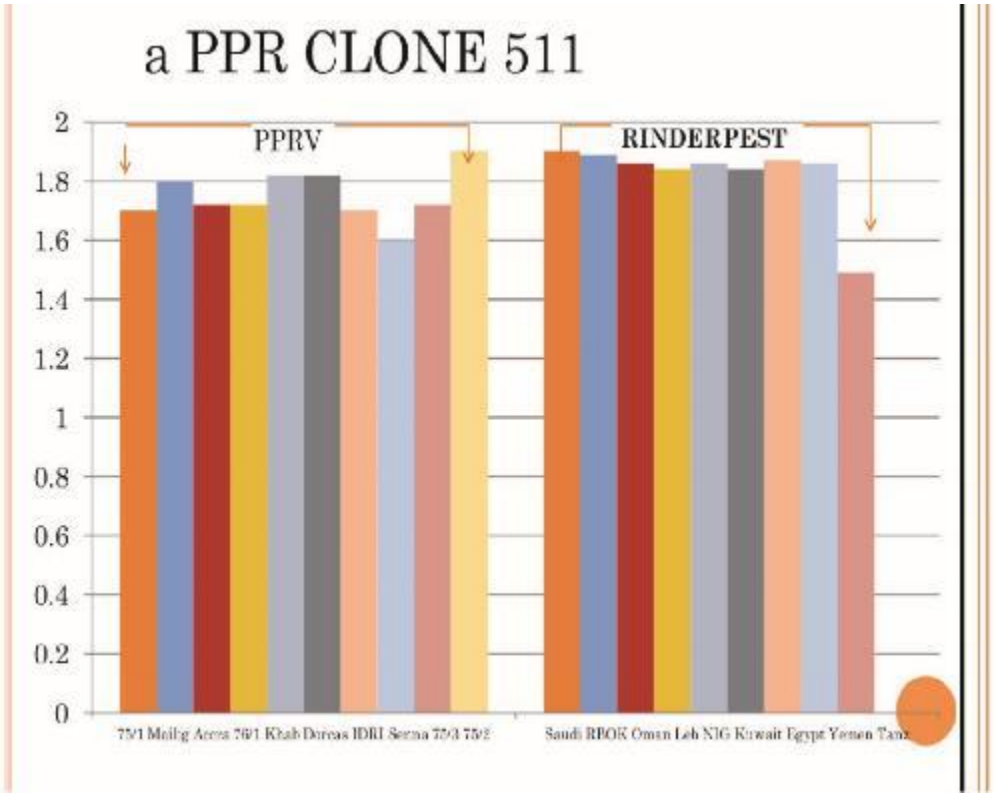

Figure 4: Cross-reactive Clone 511.

Our PPR and Rinderpest MAbs. were used in indirect and competitive Enzyme Linked Immunosorbent Assay (ELISA) to assess the reactivity against PPR isolates from Nigeria, Ghana, United Arab Emirates.

I also studied the effect of the method of virus growth (supernatant or cell associated virus), time of virus harvest, and different chemical treatment regimens on the reactivity of Rinderpest and PPR virus antigens. I found out that it was best to harvest the virus at maximum cytopathic effect before the cells detached from the growth bottles and that although both supernatant and cell-associated virus harvests gave good results in ELISA test/the supernatant antigen gave less background noise. (Obi 1993).

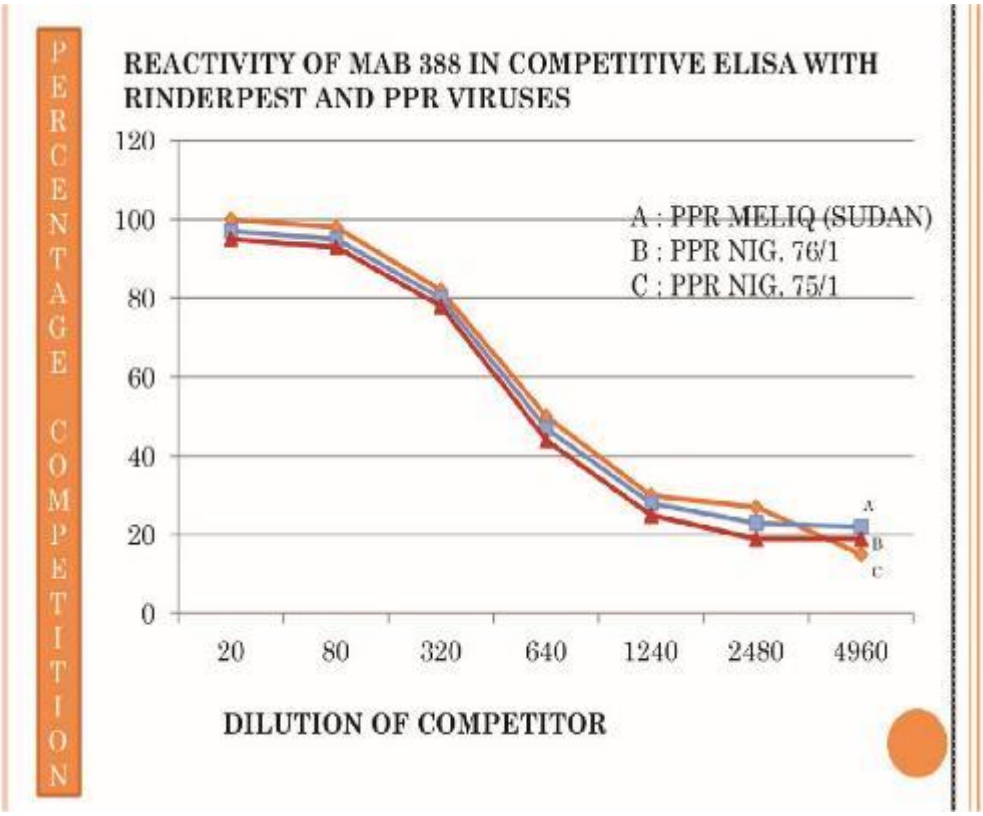

Fig.5: Reactivity of MAb 388 with PPR viruses.

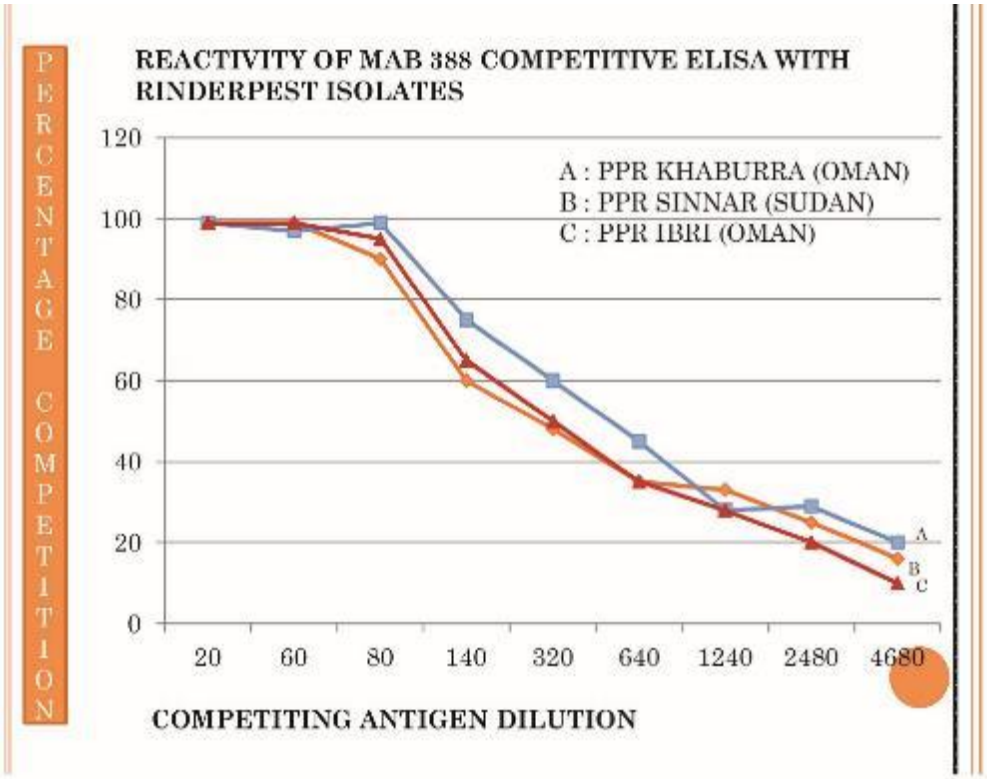

Fig. 6: Reactivity of MAb 388 with PPR viruses

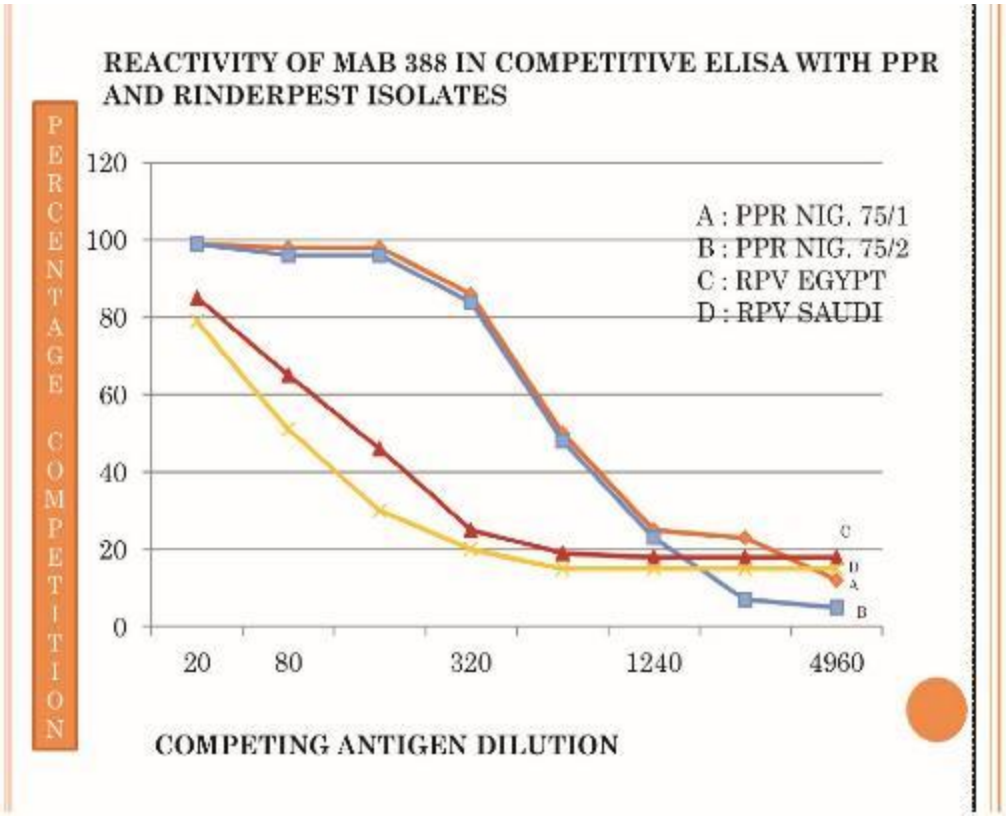

Fig. 8: Reactivity of MAb 388 with Rinderpest and PPR viruses

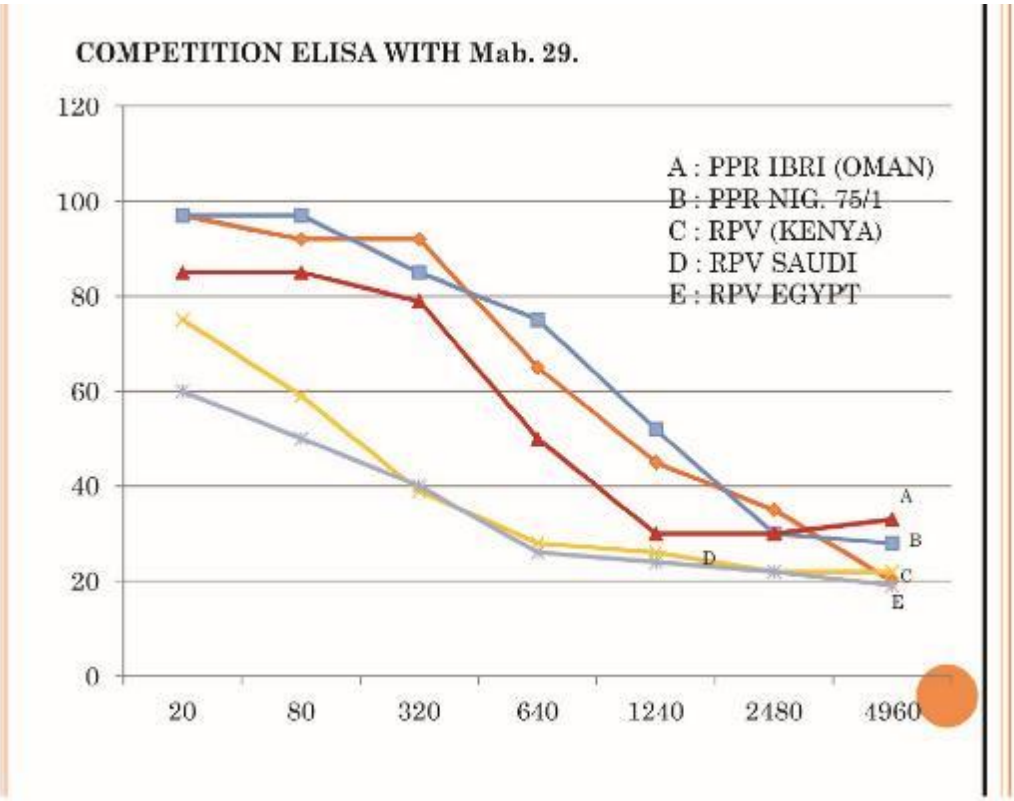

Fig. 9: Differentiation of some PPR from some Rinderpest viruses.

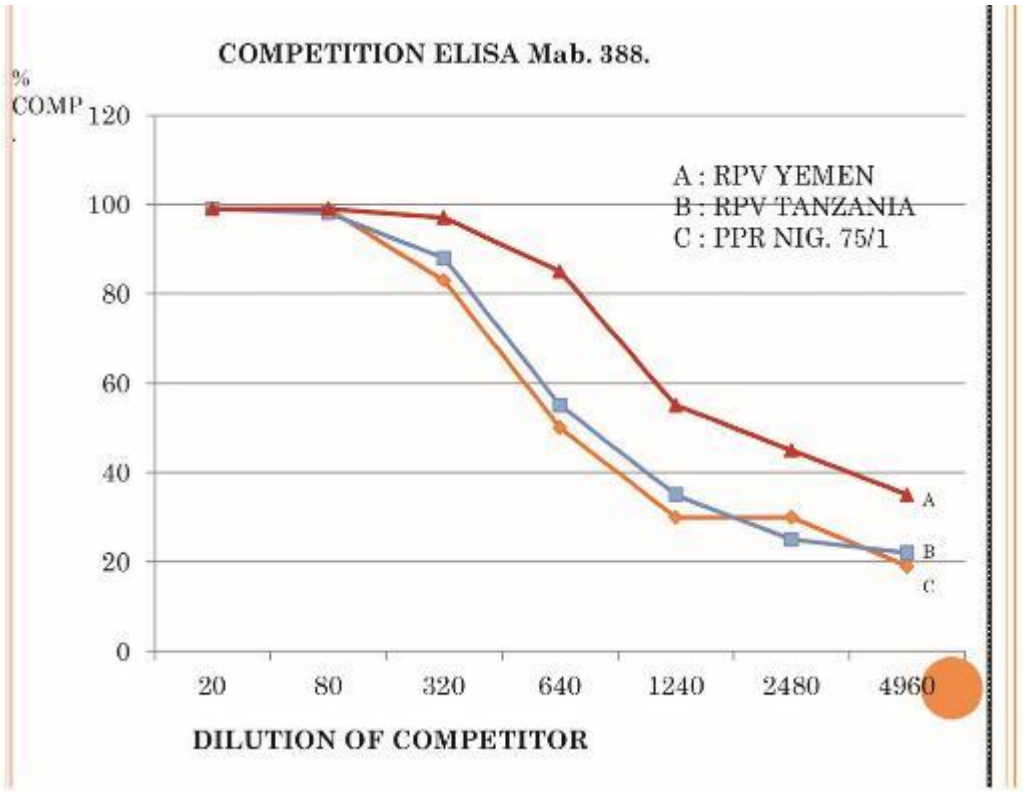

Fig. 10: Differentiation of some PPR from some Rinderpest viruses.

CONTROL AND ERADICATION OF RINDERPEST

The control and eventual global eradication of Rinderpest was a drawn out battle that spanned many years. The first control method was by immunization of cattle with serum of recovered animals (semmer et al 1893). This was followed by administration of immune serum followed by live virus (serum-virus) method. Although this produced long-lasting immunity, the immunity was not perfect as some of the vaccinated animals developed overt clinical disease. This method soon gave way to attenuated vaccines produced by treatment with Eucalyptus chloroform or formalin (AU-IBAR 2011). Again the immunity was inconsistent and sometimes short-lived. Other vaccines that were used included goat-adapted vaccines, egg-attenuated, and rabbit-attenuated vaccine (Edwards 1930, Plowright (1962) Nakamura et al 1938). It was not until later that Plowright produced an attenuated vaccine by serial passage in tissue-culture; Tissue Culture Rinderpest Vaccine (TCRV). This was the vaccine that was used world-wide including Nigeria in the last battles against Rinderpest and the production of thermo stable TCRV (House and Mariner 1996) contributed to eventual global eradication of the disease.

In Nigeria, the control of Rinderpest was carried out in three phases; the Joint programme 15 (JP 15) from 1962-1973), the Pan African Rinderpest Campaign (PARC) 1986-1999, and the Pan African Control of Epizootics (PACE) 1999-2007. Under the PARC, three viral Epidemiologists- Dr. K. Majiyagbe of the National Veterinary Research Institute (NVRI) Vom, Professor C.D. Ezeokoli of ABU Zaria, and myself from the University of Ibadan, were required to sero-monitor the Rinderpest vaccination to ensure effectiveness

of the vaccinations. In 1990, I examined a total of 7352 sera from 188 herds in 15 states in South-West, South-East, and South-South Nigeria and found that, despite vaccinations, only 40.4% of the animals were immune. In 1992 and 1993, only 35.3% and 44.9% were immune respectively. One may wonder why the antibody levels were so low. It was either that vaccinations were not being done, or because of factors inherent in the method of storage, transportation, or administration of the vaccines. A good vaccine should be cheap, safe, fast-acting, require a short interval between administration and induction of immunity, amenable to administration with other vaccines, and stable for long periods under tropical conditions. The Plowright Rinderpest vaccine is highly heat labile and requires cold storage from manufacture to administration. Hence, global rinderpest eradication benefited from the production of heat-stable tissue culture vaccine (House and Mariner 1996).

HIGHLY PATHOGENIC AVIAN INFLUENZA (HPAI) IN NIGERIA

HPAI was first reported in Italy 1878, South Africa 1961, USA 1971, Australia 1975, England 1979, Ireland 1983, Mexico 1994 and Pakistan 1994. In recent years, HPAI has become topical in Asia including Peoples Republic of China (1996), Hong Kong (1997, 2001, 2002, and 2003), Cambodia, Indonesia, Japan, Malaysia, Republic of Korea, Laos, Taiwan, Thailand, Vietnam, Turkey and Romania (2005) (OIE 2005). The most serious epidemic in recent times was in Hong Kong (1997-1998 and 2003), the Netherlands (2003), and South-Korea 2003.

Avian Influenza Viruses (AIVs) are members of the family Orthomyxoviridae and genus Influenza A. The influenza viruses that constitute this family are classified into types A, B or C based on differences between their nucleoprotein and matrix protein antigens. AIVs belong to type A. Influenza viruses are further categorized into subtypes according to the antigens of the haemagglutinin (H) and neuraminidase (N) projections on their surfaces. There are 15 haemagglutinin subtypes and 9 neuraminidase subtypes of influenza A virus, and AIVs viruses have representatives in all of these subtypes. However, to date all highly pathogenic AI viruses that cause generalized rather than respiratory disease belongs to either the H5 or H7 subtypes. For example, the classical fowl plague virus is H7N7 and the virus responsible for the major epidemic in the eastern United States in 1983/84 was H5N2. However, not all H5 and H7 viruses are virulent for poultry.

As a result of the threat of H5N1 disease spreading into Nigeria from parts of Africa and Asia, an Expert Committee under my Chairmanship and technical guidance was set up in December 2005 to develop strategies towards prevention of the introduction of Avian Influenza into Nigeria, develop a surveillance network against the disease, and prepare an emergency preparedness plan for the disease in Nigeria. The risk factors of introduction of Avian Influenza into Nigeria included the fact that the country lies in the East Africa/West Asia fly ways and the North Atlantic flyway of the migratory birds. Also the presence of AI in South East Asia and South Africa and increased trade and human traffic with Nigeria increases the risk of introduction of the disease. The present expansion of infection zone of AI is due to globalization and relative ease of movement and transportation. Nigeria's long porous borders and informal livestock movement/trading across the border especially at border markets and smuggling/illegal movement of poultry and poultry products into Nigeria as well as inadequate veterinary quarantine facilities and manpower are additional risk factors.

The risk of sustenance of the disease is considered high due to structure of the poultry industry in Nigeria consisting predominantly of backyard poultry with little or no biosecurity and peri-urban and urban commercial poultry production with minimum to moderate biosecurity and constant introduction of new birds from relatively unknown and unverifiable sources. In addition, the rearing of flocks of different species of poultry and different ages together as well as uncontrolled livestock and poultry movement within the country as a result of lack of enforcement of animal disease control laws and regulations in the country increases this risk. Reduced poultry/human interface, lack of organized poultry marketing and existence of open live poultry markets characterized by interspecies mixing, poor sanitary conditions lack of registration and licensing of poultry farms, hatcheries and establishments as provided by the law increases the risk of sustenance. In addition, inadequate early warning and early reaction capabilities including inadequate experience of most animal health workers in the recognition and diagnosis of HPAI, deteriorating animal health delivery services due to inadequate funding, and inefficient restructuring programme of the veterinary services, poor communication facilities for dissemination of information on AI and other TADs, lack of funding for compensation of livestock/flock owners in the event of slaughter of their animals for purposes of disease control, improper disposal facilities, and sale and consumption of sick and dead birds are added risk factors.

The Committee therefore concluded that the risk of HPAI being introduced into the country may be considered as moderate to high while the risk of its establishment and spread within the country may be rated as very high. In addition, the probable socio-economic as well as the public health consequences may be considered as very severe should the disease be introduced into Nigeria. Based on the results of risk analysis of HPAI in Nigeria, the Committee recommended that our overall policy should be modified involving slaughter of clinically affected poultry with full compensation, safe disposal of dead carcasses, adequate disinfection and decontamination, and appropriate disease surveillance to determine the origin and extent of the disease. An action plan dealing with HPAI emergency which defined the command chain from the rural setting through the state veterinary services to the national veterinary service was developed. In addition, public awareness campaigns were to be emphasized in the programme. It was therefore to Nigeria's credit that a contingency plan was in place well ahead of the advent of HPAI into the country unlike most other African and Asian countries.

The Federal Government of Nigeria officially declared the presence of Highly Pathogenic Avian Influenza on February 8, 2006. Although contingency plans for dealing with introduced HPAI had been prepared before the outbreaks, the plans had no political and legislative support for implementation before the disease struck. The HPAI emergency received immediate attention and response from the President of Nigeria leading to the setting up of an Avian Influenza Crisis Management Centre (AICMC) in the banquet hall of the Presidential Villa and the introduction of some compensation to affected farmers whose farms had to be depopulated in an effort to contain the disease. Three Committees, namely, the Steering, the Technical, and the Communication Committees were also formed in the AICMC to guide and coordinate AI disease control efforts.

The Food and Agriculture Organization in Nigeria; FAO-NG, acting as the leader of an international response, set up immediately an AI control room in the United Nations (UN) building and formed an AI Task Force. FAO-NG in collaboration with USAID and the French Embassy organized training workshops for animal health technicians and stakeholders in emergency preparedness and response to AI.

Assistance in the form of needed Personal Protective Equipment (PPE) was received from USAID, United States Department of Agriculture's Animal and Plant Health Inspection Service (USDA/APHIS) and the Government of Israel. Technical assistance was also given by the French Embassy, EU, DFID, the Japanese Government, and the World Bank. Despite control measures, the disease spread eventually to 97 Local Government Areas of 25 states and the Federal Capital Territory as of early March 2008.

The reaction of the international community to the status of HPAI was dominated by public fear and worry about 'imminent, ominous, inevitable overdue' pandemic. A tendency of construction of 'dangerous places, countries, and people where disease comes from was noticed in the utterances of highly placed individuals and organizations to the extent that Nigeria was described as a 'distributor of disease (HPAI) in one international telephone conference where the individual forgot I was participating in the telephone conference. Attitudes ranged from Western anxieties about globalization, outbreaks emerging from 'disrupted primordial settings', and 'protecting the conditions of modernity where disease is controlled unlike in primitive backward unregulated contexts where diseases emerge'. With particular reference to Nigeria, HPAI was at different times said to be endemic, entrenched or dug-in, terms that were reminiscent of under-developed, developing or least developed. Based on the above concerns, the international community put great pressure on Nigeria to adopt vaccination as additional control measures. Indeed, the EU was prepared to assist Nigeria with about 4 million Euros should the country agree to adopt vaccination. The international position was that vaccination is a single tool in a comprehensive strategy involving Bio-security, Surveillance, and Elimination of virus by stamping out, decontamination, and safe disposal of carcasses. Vaccination, if properly carried out was said to protect against disease and deaths as well as prevent contact transmission. Because of worldwide epidemic dimension of AI and because of increased risk of human pandemic, vaccination was deemed desirable.

But at that time, available conventional vaccines included inactivated homologous LPAI H5N1 or inactivated heterologous LPAI, H5N2, H5N7. Inactivated homologous vaccine was said to give good immunity in the vaccinated but one could not differentiate vaccinated from field infected poultry. Conversely, inactivated heterologous vaccines gives good immunity and one can differentiate vaccinated from field infected (DIVA technique) birds. H5N2 Vaccine had been evaluated experimentally (Swayne Georgia, USA) and found to give full protection and reduced virus excretion 1000-10000 times over unvaccinated birds. Field studies (Hong Kong) showed that the vaccine blocked virus transmission from 18 days' post vaccination and vaccinated birds did not transmit the virus. However, the results of field vaccination against H5N1 in-+21qZ43 9} +0. +*--*+ Hong Kong, Vietnam and Cote d'Ivoire were variable because of lack of complete understanding of the epidemiological, logistic, and post vaccination monitoring factors that should inform vaccination strategies.

Officials of the Federal Department of Livestock and Pest Control Services argued that although it was true that disease had spread to new areas, for example the South West, the stamping out strategy implemented in the infected states was assumed to be reasonably successful since no new cases of disease had been reported in the depopulated and decontaminated areas. They also claimed that vaccination does not protect against infection, only against disease. That means that vaccinated birds could continue to maintain the virus and pollute the environment and if the situation is not properly managed, could cause the disease to become endemic in the country. It should be pointed out that although vaccination did not afford 100% protection, the few birds that may not be immune may shed virus but virus load in aggregate would be lower compared to a situation where no vaccination is carried out. Also, the enormous cost of nationwide mass vaccination, which they claimed must be repeated 2 - 4 times per annum, could not possibly be mustered within the required time. There was no firm commitment from any agency to support the full cost of vaccinating the national flock. Procurement and importation of vaccine must be centrally controlled to prevent introduction of unsuitable and unsafe vaccines of dubious origin into the country. Other Nigerian government opinion included that vaccination should be regarded as a second line of defense after biosecurity, the decision to vaccinate must be taken in advance and thoroughly considered and not in a haste. They insisted that effective surveillance, disease monitoring and a technique for differentiating infected from vaccinated animals (DIVA) should be in place before vaccination would be adopted. Although they claimed that protective immunity using the inactivated vaccine lasts about or less than two months, published results in HPAI scientific literature showed that vaccine-induced immunity lasts for about one year after initial vaccination followed 4-6 weeks later by a booster dose.

Nigeria's insistence that a detailed investigation should be carried out to determine the epidemiological status of the disease in the country, especially among rural poultry, as well evaluate the effectiveness of the current actions being implemented to control the disease, (modified stamping out involving depopulation, decontamination, movement restriction and payment of compensation) should be carried out to determine the need for vaccination was justifiable. Although this was never stated, there was the possibility that the international community-driven

vaccination was possibly a trap which will militate against Nigeria's export trade in poultry and poultry materials to neighboring West African countries since it was not easily possible to differentiate vaccine antibodies from those due to field challenge.

Although the official Nigerian position was against vaccination, as a control option, investigations carried out by FAO-Nigeria Team confirmed un-approved use of two types of vaccines, a heterelogous H5N2 mainly in the South West and bivalent H5N9/H7N1 vaccines in Kaduna and Plateau states by poultry farmers. Contrary to the claims from the FDL&PCS that the vaccines spread HPAI into uninfected farms, it is my considered opinion that vaccination procedures characterized by the use of contaminated clothing and equipment such as syringes/needles and de-beakers by private professional and non-professional animal health service providers may have been responsible for disease spread.

The overall policy for HPAI emergency Nigeria was to restrict the disease to the primary foci, eradicate the disease in the shortest possible period and limit the economic and public

health impact using modified stamping out which involved quarantine and slaughter of infected poultry with full compensation; sanitary disposal of destroyed poultry and contaminated poultry products according to standard operating procedures; quarantine and movement control on poultry and poultry products in the infected areas or zone and decontamination of facilities, products and equipment to eliminate the virus on infected premises and prevent spread to other areas. This was strengthened by active disease surveillance to determine the source and extent of the infection and effective public awareness campaign to elicit cooperation from large scale commercial and back yard poultry owners.

The Avian Influenza Active Disease Surveillance was carried out in all the 36 States of the Federation and the Federal Capital Territory (FCT) while the Live-Bird Market Surveillance study was carried out in 54 markets in 26 states in which HPAI had been confirmed. The Active HPAI surveillance was designed in a way to ensure 95% probability of detecting one positive case given a 20% prevalence of HPAI in the study area. A total of 4,064 tracheal, 3,913 cloacal, and 3,166 serum samples were examined during the nation-wide HPAI surveillance study while 4,501 tracheal, 4,484 cloacal, 616 carcasses, and 4,275 serum samples were examined in the targeted live-bird market surveillance. Data obtained from questionnaires that were administered to the poultry owners indicated about 6.5% prevalence of HPAI in the study area and failure to detect one virus or viral antibody positive case may have indicated that the prevalence of HPAI in mainly non-commercial rural extensive poultry may be less than 20%. Given an estimated 140 million birds in the country and 95% confidence, it was calculated that the maximum number of H5N1 positive birds will be 85,705 (0.06%). It is being recommended that a customized participatory rural disease search be carried out in the village scavenging poultry production system.

It was observed that majority of the LBMs hold on daily basis without any resting period and is situated right in the middle of the larger markets and birds sold amidst marketers of other food items and related market wares. It is being recommended that at least one day in the week should be set aside for the cleaning and disinfection of LBMs and that many of the LBMs should be relocated out of the major markets or at the worst separate poultry sections should be created out of the main markets. This should form part of the restructuring and rehabilitation programme for poultry production and marketing systems in Nigeria.

Fig.11: Domestic chickens. Pigeons ducks all in one basket in a LBM in Nigeria.

Fig 12: Young chicks kept in a basket on top a metal cage holding Old birds.

The observed and common practice for mixed species of poultry to be sold together, housed in the same cages, including young chicks, creates likely sources of introduction of HPAI into hitherto uninfected villages since replacement stocks for village poultry keepers are purchased from these markets. It is being recommended that a study be carried out to help establish, as part of a pro-poor HPAI control programme, the desirability, feasibility and sustainability of a scheme for the production by the rural farmers, individually or as cooperatives, of day-old local/indigenous chicks as replacement stock for the village poultry producers.

Generally, the level of bio security in the LBMs was found to be un-acceptably poor. Poultry cages, mainly constructed from wood or cane were not cleaned, sick birds were not usually separated from the healthy ones, are either sold at lower prices or slaughtered and processed for human consumption to minimize losses. Facilities for safe disposal of dead birds were grossly inadequate. Considering the fact that about 85% of the poultry sold in these markets are slaughtered in the LBMs at customer's request, it is being recommended that a more bio-secure system of mechanized slaughter and processing of poultry should be an integral part of any restructuring of the poultry marketing and processing system to reduce human exposure to the virus.

The isolation of H5N1 virus in 5 out of the 54 LBMs from chickens in three states, from a sick duck in one state and detection of Avian Influenza genetic materials from a chicken in another state, confirmed that LBMs are important in the spread and maintenance of HPAI in Nigeria and also points to a high risk of human exposure to the virus in LBMs. It is recommended that that LBM surveillance should be carried out at least twice a year. Fifty Newcastle Disease Virus (NDV) isolates were obtained from 17 of the 26 states from

chickens, guinea fowls and a pigeon indicating that NDV is widely prevalent in the country despite repeated vaccinations that are routinely carried out in various farms. It is being recommended that the Nigerian Government should use the opportunity of the HPAI emergency to mount a similar response to ND and that ND surveillance should be integrated into any HPAI disease surveillance.

The project achievements include, the carrying out of the first nation-wide active disease surveillance in poultry in Nigeria, the establishment of an effective system of sample collection, preservation and dispatch to the national laboratory in satisfactory conditions within 24-72 hours, as well as capacity building by training 207 field surveillance officers in HPAI disease surveillance and 8 university laboratory scientists in modern techniques for the diagnosis of HPAI. Others include confirmation of H5N1 virus in LBMs in Nigeria and thus indicating a role in the spread of HPAI in the country and human exposure to the virus. The project succeeded in the identification of essential characteristics of the LBMs including management systems and levels of biosecurity that would be useful in any planned restructuring of the poultry marketing and processing industry in Nigeria and highlighted the need for a new initiative on Newcastle Disease control in Nigeria as an integral part of HPAI response.

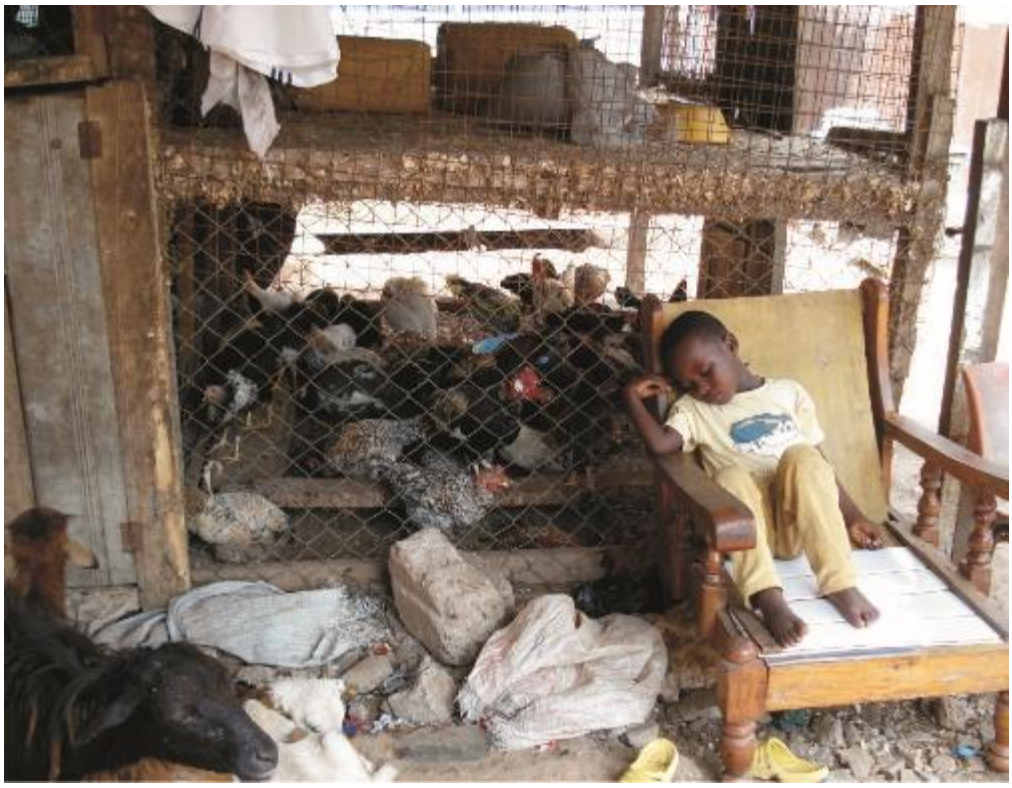

Fig 13: Innocent boy asleep outside/near a cage AI present or not.

I was then recruited subsequently as the Regional Coordinator of Stamping Out Pandemic and implement improved biosecurity in selected LBMs and small scale poultry farms in Ghana, Mali, Cote d'Ivoire, and Benin Republic. STOPAI provided motorized and Nabual

sprayers, water hoses, nose masks, strong brushes, gloves, Sodium Hypochlorite (bleach), plastic poultry transport cages, improved metal poultry cages, developed standard operating procedures, and national consultants. The national consultants trained 30 livebird marketers in Ghana, 15 in Benin, 30 in Mali and these were required to train cohort marketers. We also introduced improved biosecurity in two live bird markets in Ghana, Benin, and Mali. Two demonstration farms were used to train farmers from other regions showcasing simple affordable, but effective, on-farm biosecurity measures. We assisted the formation and registration of egg seller's associations and fowl seller's associations in these countries.

We established working partnerships with these private organizations: the Projet de Development de Aviculture au Mali, and Association National des Aviculturs Modernes and Munivipla Council in Mali, Association des Usagers des Marches Pour Actions Citoyennes Union National Des Aviculteurs Professionnels Du Benin and the directorate of Veterinary Services n Benin The Ghana National Poultry Production Association Kumasi and Domeh Fowl Sellers and Kunmasi Egg Sellers Association and Kumasi Ga North Greater Accra Municipal Council. Others include the Directorate of Veterinary Services the Proveto the IPRAVI and Angre Cocovico in Cote d'Ivoire. We also used local artisans in the fabrication of equipment such as metal cages and killing/bleeding cones thus enhancing acceptance and local ownership of the project.

I will like to suggest that the design of improved equipment like transport cages and market place housing should build on traditional designs and utilize locally available materials so that they can be produced locally. Also, government services should broker continued support for national poultry associations and establish functional private-public partnerships leading to association-based disaster insurance schemes and establish consumer targeted safe poultry awareness campaigns.

For example, traditional cages for housing poultry in LBMs and transportation are made of wood, ropes, and bamboo. But it was interesting to find metal replicas of the bamboo conical Baskets that are popular in many west African LBMs in Benin. The shape and design is maintained but metal instead of bamboo is used in the construction.
The transport cages in Niger are very interesting. They are affordable, easy to assemble and transport, and cost effective. Although they pose some challenges, they provide good opportunity to come up with some alternative that is durable, cost-effective, and amenable to cleaning and disinfection.

Fig 14: A killing/bleedings cone manufactured in Cote d'Ivoire

Fig 15: A marble top table for slaughter and processing of poultry, easy to wash and disinfect (produced in Mali)

Fig 17: Transportation of poultry in a bus in Niger.

Fig. 18: An effective but cheap foot bath at the entry to a poultry farm in Benin

Fig.19: Cheap fence for a small scale poultry farm in Benin

Acknowledgements

The author gratefully acknowledges the financial support of the European Union (EU) and the United States Agency for International Development (USAID) for the surveillance studies and staff of the Federal Department of Livestock and Pest Control Services and State Veterinary Services for their active involvement in the surveillance studies. Funding for the West African Live Bird Market (LBM) and small scale farms was from USAID"

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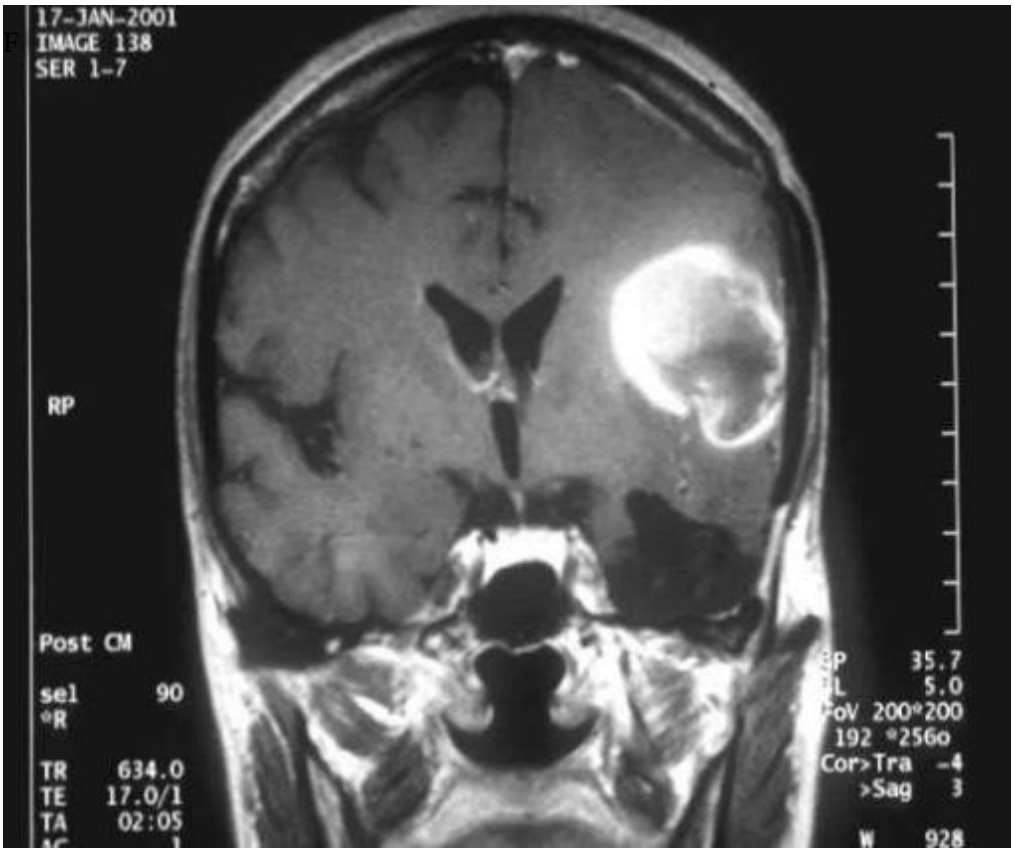
THE MINING OF NIGERIAN MEDICINAL PLANTS FOR CANCER THERAPY

PRESENTED AT THE INDUCTION OF NAS FELLOWS, 14TH MAY 2015, REIZ CONTINENTAL HOTEL ABUJA



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PROFESSOR ISA MARTE HUSSAINI

FELLOW OF NIGERIAN ACADEMY OF SCIENCE

OVERVIEW

What is Cancer?

Causes of Cancers and Statistics Cancers

- Advances in the Management and Treatment of Cancers
- The use of Traditional Medicines in the Treatment of Cancers
- Ethnomedical Survey and Anti-cancer Screening of Nigerian Medicinal Plants

Introduction

Tumour is an abnormal growth of cells which form a mass called neoplasm. When the tumor is slow growing and confined to a certain organ it is called benign. Sometimes the tumour can progress into a malignant phenotype while in some situations the cancer cells break away from a tumour mass and spread to other tissues or organs such as the brain and bones through the blood or lymph system. The tumour cells can settle in new places and form new masses. When this happens, the process is called metastasis. This type of neoplasm is called cancer. However certain tumours such as astrocytomas (brain tumors) even when malignant hardly metastasize outside the brain. In contrast breast, prostate and other cancers can metastasize to the brain.

Cancer occurs when cells in a part of the body begin to grow out of control. Normal cells divide and grow in an orderly fashion, but cancer cells do not. They continue to grow and crowd out normal cells. Although there are many kinds of cancers, they all have, in common, this out-of-control growth of cells. Other hallmarks of cancers include; sustained angiogenesis (increased blood vessel supply), high invasive and migratory rates, ability to overcome programmed cell death (apoptosis), limitless proliferative potential, insensitivity to anti-growth signals and self-sufficiency in growth signals (Hanahan and Weinberg , 2000). Different kinds of cancers do not behave in the same manner. For example, lung and breast cancers are very different diseases. Cancers grow at different rates and respond to different treatments. As a result of the heterogeneity of cancers, treatment strategies should be tailored to be patient and cancer-specific.

Causes of Cancers

There are many factors that are implicated in the genesis of cancers and these include genetic and environmental factors. Cancer may result from DNA Mutations which may be caused by (1) radiation and other environmental factors (such as tobacco, alcohol, radon and asbestos), (2) random somatic mutations, (3) inherited germline mutations or genetic predisposition of certain genes such Rb, Ras, p53, APC, CDKN2A, BRCA1, BRCA2 and EGFR. Infectious agents such as viruses may also cause cancer. For example, human papillamavirus (HPV) is involved in cervical cancer and Hepatitis is implicated in liver cancer. Vaccines have been developed for both HPV and Hepatitis which are extremely effective. The bacterium, Helicobacter pylori is implicated in the development of stomach cancer. In case of brain tumours, ionizing radiation, genetic alteration (neurofibromatosis) and certain diets have been shown to predispose the disease. Over the last ten years, cell phones have been suspected to cause brain tumours but large scale investigations in Europe

and the United States failed to provide conclusive evidence linking cell phones to brain tumours in humans. However, in June 2011, the WHO has included cell phones in the category of carcinogens as a result of new evidence that implicated these devices in the genesis of gliomas.

Cancer Incidence and Mortality

Cancer is now the second leading cause of death in the US and Europe, heart disease is number one (See Table1). In the developing countries, cancer is usually considered as a disease of the western world but that is completely wrong. According to the WHO cancer kills more than HIV/AIDS, tuberculosis and malaria combined. The International Agency for Research on Cancer predicts that the annual new cases of cancers are expected to rise from 11 million in 2000 to 16 million in 2020, some 70% of which will be in developing countries.

Table 1 USA Mortality, 2003 (American Cancer Society)

Rank	Disease	No. of Death	% of All Death
1.	**Heart Diseases**	**685,089**	**28.0**
2.	**Cancer**	**556,902**	**22.7**
3.	**Cerebrovascular diseases**	**157,689**	**6.4**
4.	**Chronic lower respiratory diseases**	**126,382**	**5.2**
5.	**Accidents (Unintentional injuries)**	**109,277**	**4.5**
6.	**Diabetes mellitus**	**74,219**	**3.0**
7.	**Influenza and pneumonia**	**65,163**	**2.7**
8.	**Alzheimer disease**	**63,457**	**2.6**
9.	**Nephritis**	**42,453**	**1.7**
10.	**Septicemia**	**34,069**	**1.4**

In males, there are more cases of prostate cancer diagnosed than any other cancer, while in females' breast cancer is more prevalent than other cancers. Among the cancers, pancreatic cancer is the deadliest with mean survival time of 6 months, followed by glioblastoma multiforme (WHO grade IV malignant brain tumor) which has an average survival period of 9-12 months.

Men 720,280			**Women 679,510**	
Prostate	33%		31%	Breast
Lung & bronchus	13%		12%	Lung & bronchus
Colon & rectum	10%		11%	Colon & rectum
Urinary bladder	6%		6%	Uterine corpus
Melanoma of skin	5%		4%	Melanoma of skin
Non-Hodgkin lymphoma	4%		4%	Non-Hodgkin lymphoma
Kidney	3%		3%	Thyroid
Oral cavity	3%		3%	Ovary
Leukemia	3%		2%	Urinary bladder
Pancreas	2%		2%	Pancreas
All Other Sites	18%		22%	All Other Sites

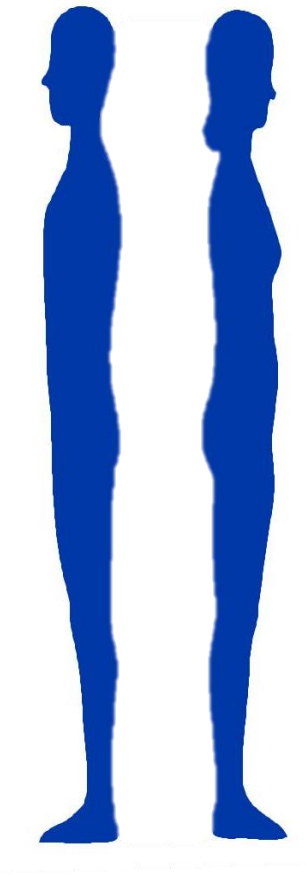


Fig. 1 US Cancer Cases 2006; Source - American Cancer Society

Although the incidences of prostate and breast cancers are highest in men and women, respectively, the rate of cancer death per year is greater with lung cancers than prostate and breast cancers in both genders. This is largely attributed to advancement in early detection techniques for breast and prostate cancers but not lung cancer.

Men 720,280			**Women**	**679,510**
Lung & bronchus	31%		26%	Lung & bronchus
Colon & rectum	10%		15%	Breast
Prostate	9%		10%	Colon & rectum
Pancreas	6%		6%	Pancreas
Leukemia	4%		6%	Ovary
Liver & intrahepatic bile duct	4%		4%	Leukemia
Esophagus	4%		3%	Non-Hodgkin lymphoma
Non-Hodgkin lymphoma	3%		3%	Uterine corpus
Urinary bladder	3%		2%	Multiple myeloma
Kidney	3%		2%	Brain/ONS
All other sites	23%		23%	All other sites

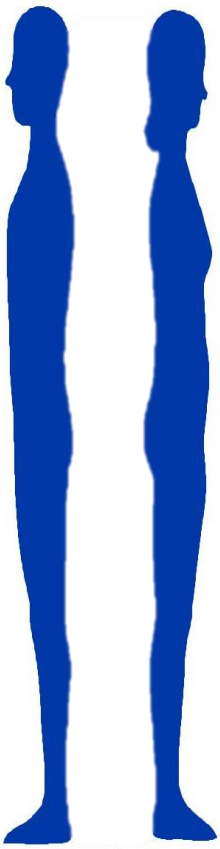


Fig. 1 US Cancer Death: Source - American Cancer Society Website

In a preliminary study conducted at Ahmadu Bello University Teaching Hospital in 2006, we found out that there were more cervical cancers in women than breast cancer, while in men prostate cancer was more prevalent than other cancers in men. The incidence of lung cancers was very low and was below 4% (Mohammed, Abubakar and Hussaini, unpublished data).

Advances in the Management and Treatment of Cancers

Most of significant advances that have been made recently in the management of cancer are in the early detection of the cancers. It is imperative to "catch" the cancers before they become malignant and metastasized. A combination of mammography and manual detection of lumps in breasts have significantly saved the lives of several women from breast cancers. Similarly, analysis of prostate specific antigen (PSA) and rectal examination have helped Urologists and Oncologists to detect prostate cancers before they metastasize outside the prostate gland and become deadly. Colonoscopy has also aided the detection of pre-cancerous polyps before they progress into dangerous colorectal cancers.

Chemotherapy of cancer is the use of chemicals (drugs) to treat or manage the diseases. The treatment modality of choice depends on the stage of the cancer, age, health status and

additional personal characteristics. As a result of the high propensity of cancer cells to proliferate, earlier treatment paradigm was geared towards the regulation of the cell cycle. This treatment targets any rapidly dividing cells (normal as well as cancer cells). Chemotherapy is usually recommended for cancer cells that have metastasized because surgical resection would not be useful and whole body radiation has unwanted side effects. Most importantly, drugs that are absorbed into the blood stream can easily be distributed to the organ where the cancer is located. The cell cycle regulators (alkylating agents, vincrestine, doxorubicin) act at the levels of DNA, RNA transcription and protein translation. The problem with such an approach is that normal cells are also affected and the use of cell cycle regulator might lead to unpleasant side effects such as bone marrow suppression and alopecia.

The revolution in molecular biology and the completion of the Human Genome project in 2003 (started in 1990 and a working draft document was released 2000) have provided cancer researchers with newer therapeutic targets. Differential DNA microarray profiling and kinase screening had led to the identification of genes that are either overexpressed or suppressed in cancer cells compared with their normal counterpart cells, which makes these genes unique targets for therapeutic intervention. Epidermal growth factor receptor

(EGFR), a tyrosine kinase 7-transmembrane receptor, is overexpressed/overamplified (increased gene copy number) by over 40%-60% in number of cancers and tumors including primary glioblastoma multiforme (WHO grade IV brain tumor, GBM), lung and rectal cancers. The Increased expression level or gene copy number of this receptor has been associated with poor prognosis (Herbst 2004). Mutation of EGFR in cancers results in the truncation of the receptor producing a constitutively active EGFR vIII (Kuan, Wikstrand and Bigner 2001). Antibodies (Cetuximab, Zalutumumab) and tyrosine kinase inhibitor (Gefitinib) targeting EGFR have passed clinical trials and are in the clinic for the management of cancers. As a result of overexpession of EGFR, its downstream targets such as Ras, Raf, mitogen activated kinase (MAPK), Akt and mammalian target of rapamycin (mTOR) are putative targets in chemotherapy of cancers (Figure 3). Since two or more pathways are activated following EGFR activation, the recommended approach is the use of a combination therapy to block the pathways involved.

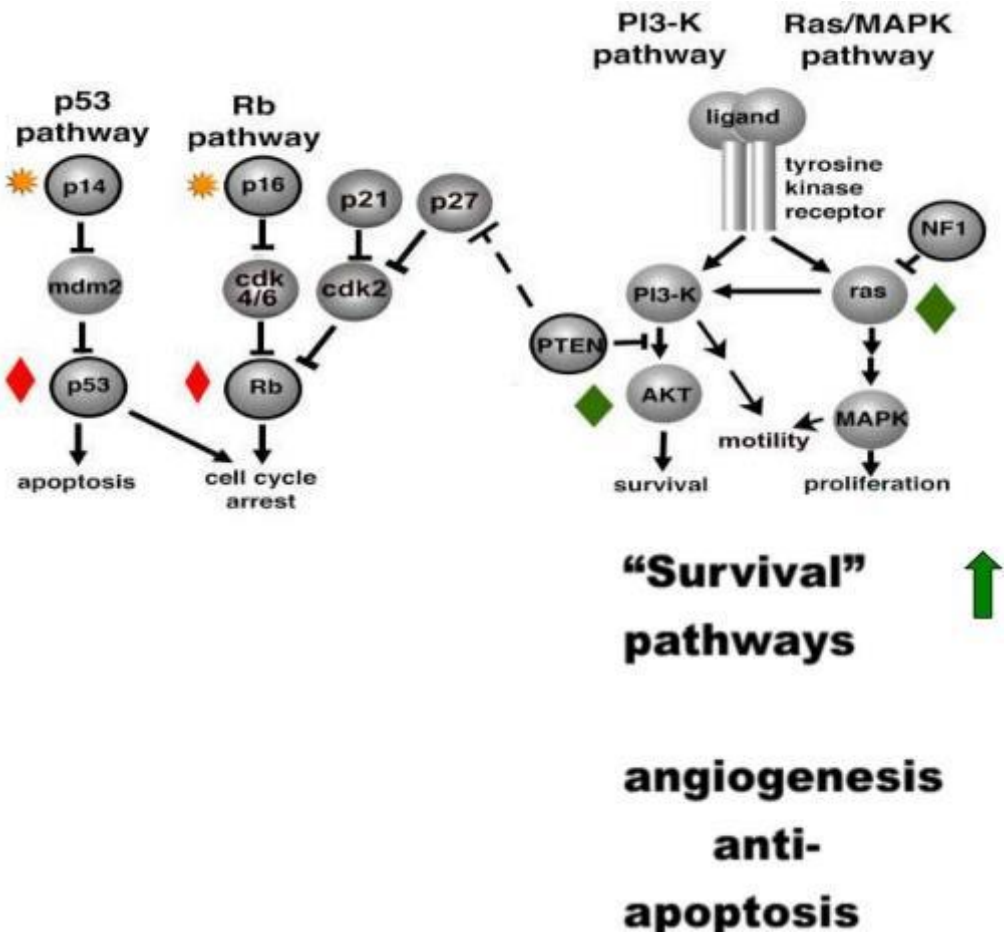


Fig. 3 Signal transduction pathways involved apoptosis, cell cycle arrest and invasive growth

Another EGFR family Her2 is overproduced in about 20% of breast cancers (Isakoff and Baselga, 2011). The HER2-overproducing cancers tend to be more aggressive and are more likely to recur. Trastuzumab, a monoclonal antibody which targets the HER2 protein is used in conjunction with adjuvant chemotherapy to lower the risk of HER2-overproducing breast cancer recurrence by 50% compared with chemotherapy alone. Various researchers have discovered several breast cancer susceptibility genes, including BRCA1, BRCA2, TP53, and PTEN. Mutations in BRCA1 and BRCA2 account for approximately 80-90% of all hereditary breast cancers, and women who carry mutations in these genes have a lifetime risk of breast cancer that is roughly 10 times greater than that of the general population. Strategies targeting some of these genes with chemotherapeutic agents and reversing their mutations would provide new treatment paradigm for breast cancers.

The recent success of cancer chemotherapy involves the use of Gleevec (Imatinib) in the treatment of chronic myelogenous leukemia (CML), gastrointestinal stromal tumors

(GISTs). The research started in a basic science research laboratory and the product ended up in the clinic. In CML, the Philadelphia chromosome leads to a fusion protein of abl with bcr (breakpoint cluster region) which makes the tyrosine kinase constitutively active and Gleevec decreases bcr-abl activity (Deininger and Druker, 2003). Majority (95%) of CML patients who have abl-bcr fusion respond to Gleevec and the drug has very little effect on normal cells. In addition, Gleevec suppresses platelet-derived growth factor (PDGF) by inhibiting its receptor (PDGF-Rβ).

The rapidly increasing knowledge of molecular genetics, cell biology and immunology would help cancer researchers to develop more effective and less toxic cancer chemotherapeutic agents. The molecular changes that cause cells to become cancerous would be identified and targeted with drugs. Since genetic alterations vary from patient-to-patient, gene signature would be used to provide personalized cancer therapy.

Pharmacogenomic approach is also attracting attention and this would be used to determine a patient's response to chemotherapy because the tumor's genetic characteristics and inherited variation in genes affect a person's ability to absorb, metabolize, and eliminate drugs. This would allow prediction of tumor response to individual chemotherapy drugs or class of drugs. This strategy should also aid in the design of more effective and less toxic chemotherapeutic agents.

The use of Traditional Medicines in the Treatment of Cancers

The typical African health sector in the rural areas consists of traditional healers and birth attendants, who are the de facto providers of primary health care. Healers provide client-centered and personalized health care that is culturally appropriate, holistic and tailored to meet the needs and expectations of the patients (Iwu, 1994). There is also a general belief that the remedies used in traditional medicine are safe and more readily acceptable by the body. This is far from the truth because of the numerous reported cases of toxic and lethal effects of herbal medications.

One of the major challenges facing traditional headers is the lack of knowledge in proper diagnosis of diseases such as cancer. Some believe that cancers occur as a result of contact of patients with evil spirits in the forest or bush and thus the general term “daji” (bush in Hausa) to describe cancer. Interestingly, some of Traditional Medicine Practitioners (TMPs) have some basic knowledge of specific cancers, for example they describe leukemia and believe that it is inherited. However, they believe that leukemia is more frequent in families with a history of sickle cell anemia. The latter may have some medical and scientific merits.

The use of plant-derived medications dates back to pre-historic periods. Modern plant-based drugs were discovered as early as late 17th century and they include aspirin (analgesic), morphine (narcotic analgesic), digitalis (antiarrhythmic agent), and quinine (anti-malarial). Some plant alkaloids such as vinblastine and vinblastine (Vinca Alkaloid) are used to manage cancers. Recently, Paclitaxel (Taxol) was isolated from Yew tree and is now used for the management of melanoma, ovarian, lung and breast cancers.

Plant Name	Family	Local Name	Part Used	Cancer- type
Cissus ibuensis Hook	Ampelidaceae	Daddori	Leaves	Skin cancer
Annona senegalensis Pers.	Annonaceae	Gwandar daji	Stem bark/leaves	Skin cancer/leukemia
Aristolochia albida Dulchartre	Aristolochiaceae	Duman dutse	Rhizomes	Many forms of cancers
Leptadenia hastata Pers	Asclepiadaceae	Yaadiya	Aerial parts	Cancers in general
Maytenus senegalensis Lam.	Celastraceae	Mangaladi	Leaves	Cancers in general
Ximenia Americana Linn.	Olacaceae	Tsaada	Fruits	Many forms of cancers

In 2006, we carried out an ethnomedical survey of medicinal plants used in the treatment of cancers among the Hausa-Fulani tribes in Kaduna State (Abubakar, Adamu and Hussaini, 2007). We found a number of plants that are used in the treatment of "daji" (cancer) and these are presented in Table 2.

In 2012, we discovered another plant, Senna siamea (family = fabaceae) that showed anti-tumor activity. An undergraduate student (Nasiru) of the University of Maiduguri under the supervision of Pharmacist Yabalu Abacha (Department of Pharmacognosy) screened the Senna parts for cytotoxicity using shrimps and later we extended the study to human brain tumours. Senna root extract was incubated with malignant brain tumor (glioblastoma multiforme; GBM) for 48 hours. GBM cells were washed three times and fixed with 1% crystal violet. The cells were then photographed under microscope. The ethanol extracts (50 – 250 □g/mL) of senna siamea roots and leaves were screened for anti-tumor activity against GBM cells. The root extract was effective in killing the tumor cells at a low dose of 50 □g/mL while the leaf extract was not effective at even 250 □g/mL. Figure 4 shows untreated (control) and extract-treated (250 □g/mL) GBM cells. The root extract killed over 70% of the tumor cells within 48 hour.

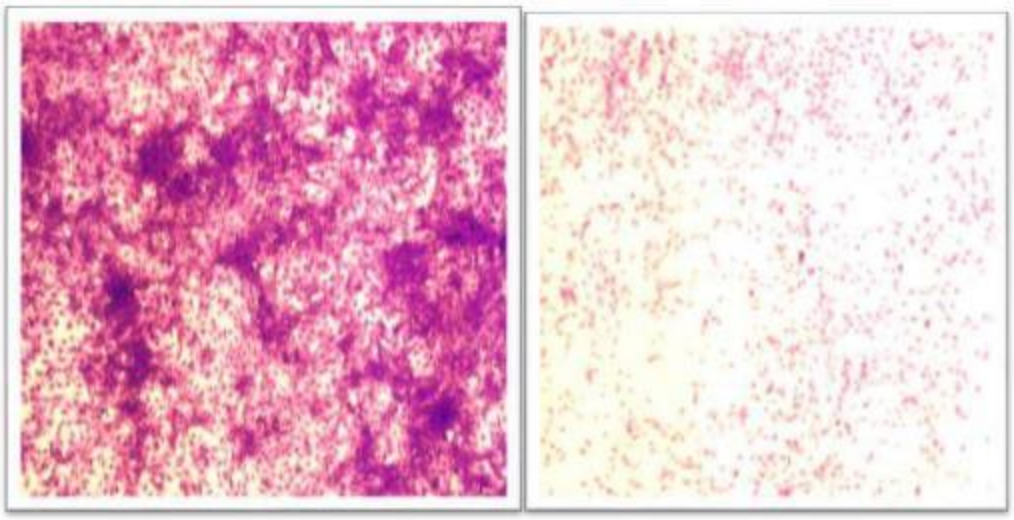


Fig. 4 - Anticancer Activity of Senna siame

In a preliminary study, we tested N. sativa seed (Black Caraway) for anticancer activity. The plant is extensively used in the Middle East, North Africa and Borno State for the treatment of a variety of ailments, including epilepsy, inflammation, asthma and others. The ethanol (BC-ETOH) and hexane (BC-H4) fractions of the seeds of N. sativa killed brain tumours (Figure 5). The results were generated by counting the number of tumour or cancer cells before and after treatment with the ethanol extract of the plant. The anticancer activity was associated with the oil fraction of the seed which also activated caspases-3 and 9 (death-mediating genes) and down-regulated insulin growth factor receptor-1 (survival factor). These factors are involved in tumorigenesis.

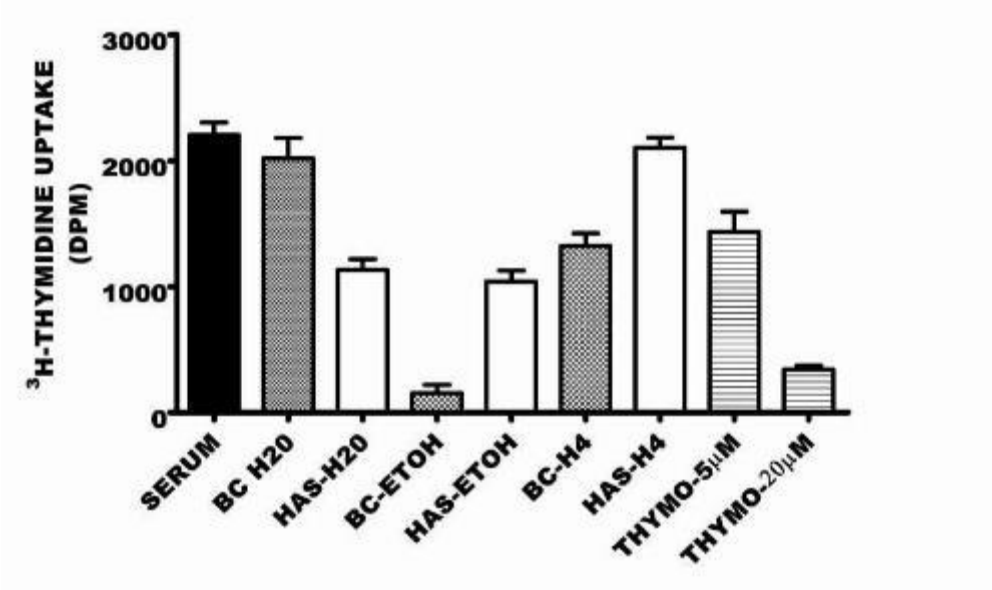


Fig. 5 Anti-proliferative activity of different fractions of Black Caraway and thymoquinone on glioblastoma cells.

Using Mass Spectrometry and nuclear magnetic resonnance (NMR), we identified the active compound as thymoquinone. The IC50 values for the oil fraction of black caraway and thymoquinone were determined to be 250 □g/ml and 6.0 □M (n=5).

N. sativa oil and thymoquinone-induced apoptosis in GBM cells - To determine the mechanism(s) of N. sativa seed oil-induced GBM death, we performed propidium iodide (PI)/Hoescht staining to assess the number of dead/apoptotic cells. The Hoescht dye has the property of freely passing through the plasma membrane and readily enters cell with intact membranes as well as cells with damaged membrane and stains blue, whereas PI (a highly polar dye) is impermeable to cells with preserved membranes and stains red. In Fig. 6, it is clear that N. sativa (250 □g/ml) and thymoquinone (10 □M) treatment significantly killed more malignant brain tumours compared with control. We had also confirmed the efficacy of both the oil and thymoquinone in our xenograft animal model.

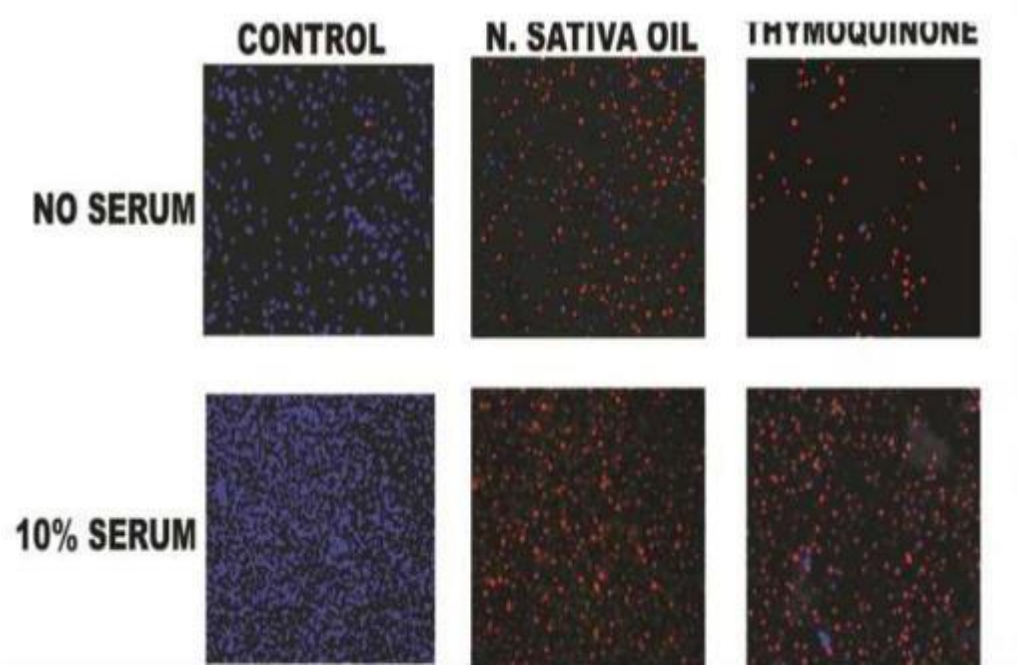


Fig 6. Propidium Iodide/Hoescht Staining of Astrocytoma Cells

Ethnomedical Survey and Anti-cancer Screening of Nigerian Medicinal Plants

Cancer Prevalence - Cancer is the second leading cause of deaths in many countries and there is no cure for most of the diseases. In Africa, traditional medicine practitioners (TMP) claim to have effective treatments for what they diagnose as “cancers”. The cancer research

project at the University of Maiduguri used scientific techniques to validate the rationale for the folkloric use of herbal medications by TMP. To find out the types of cancers diagnosed in the North East geopolitical zone of Nigeria, we collected data from patients who attended the University of Maiduguri Teaching Hospital for the treatment of cancers for 5 years (2006 – 2011). Prostate and skin cancers were more common in men and breast and cervical cancers were more prevalent among women (Table 3). Based on this finding, we are now focusing our studies on these cancers and brain tumours. The latter is the second deadliest tumour/cancer. Three Co-PIs (Dr. Bala Audu, Dr. Babayo Usman and Dr. Ahmed Mayun) will continue to work on this aspect of the project and establish a Cancer Registry for the North Eastern region of Nigeria.

Table 3 - Leading cancer-types registered at the University of Maiduguri Teaching Hospital 2006-2011 (5 Years)

SITE	NUMBER	FREQUENCY
BREAST	**357**	**17.0**
CERVIX	**318**	**15.1**
PROSTATE	**232**	**10.9**
SKIN	**224**	**10.6**
GIT	**208**	**9.6**
ENT	**179**	**8.5**
OVARY	**91**	**4.1**
BLADDER	**64**	**3.0**
STOMACH	**41**	**1.9**
ENDOMETRIUM	**33**	**1.6**
TOTAL	**2104**	**100.0**

In the second part of the study, ethnomedical survey of plants used in the treatment of cancers (daji) in the North-East geopolitical zone of Nigeria was carried out. We identified 54 plants that are used in the folkloric treatment of cancers. The botanical and local names of some of the plants are presented in Table 4.

We defatted the plant parts that are used in folkloric medicine with petroleum ether and further extracted the residue with ethanol. The dried extracts were screened for anticancer activities against well-characterized brain tumour (A171, U87 and U1242) and breast cancer (231) cell lines. The extracts were coded ETF1-54 and all screenings were carried out blind. In the initial screen three samples (ETF3, 6 and 20) out of ten extracts were found to be highly effective in killing brain tumour and breast cancer cell lines. Subsequently, we screened 44 extracts and established robust anticancer activities of 8 plants.

Table 4. Some of the Plants used in the treatment of cancers by TMPs.

S/N	Botanical name	Family name	Hausa name	Uses	Parts used
1	Boswellia dalzielli	Burseraceae	Arrarabi	Cancer	Bark
2	Commiphora Africana	Burseraceae	Dashi	Cancer	Bark, leaves, roots
3	Cadaba farinose	Capparidaceae	Bagayi	Cancer	Leaves, root, bark
4	Commiphora pedunculata	Burseraceae	Daddasa/ namijin dashi	Cancer	Leaves, root, bark
5	Maerua angolensis	Capparidaceae	Mandewa	Cancer	Leaves, stalk, bark
6	Piliostigma reticulatum	Caesalpiniaceae	Kargo	Cancer	Bark, leaves, root
7	Euphorbia hirta	Euphorbiaceae	Nonon kurciya	Cancer	Leaves, whole plant
8	Ziziphus abyssinica	Rhamnaceae	Magaryan kura	Cancer	Bark, leaves, root
9	Acacia albida	Mimosaceae	Gawo	Cancer	Bark, leaves, root
10	Guiera senegalensis	Combretaceae	Sabara	Cancer	Leaves. root
11	Acacia Senegal	Mimisaceae	Dakwara	Cancer	Leaves, bark, root
12	Terminalia avecenniodes	Combretaceae	Baushe	Cancer	Bark, leaves, root

13	Ximenia ameerica	Olacaceae	Tsada	Cancer	Leaves and bark, root
14	Capparis tomentoso	Capparidaceae	Kabdodo	Cancer	Leaves, root, stalk
15	Albizzia chevalier	Mimisaceae	Katsari	Cancer	Leaves, bark, root
16	Sterospermum kuthianum	Bigniniaceae	Samsami	Cancer	Bark, root
17	Acacia ataxacantha	Mimisaceae	Duhuwa	Cancer	Leaves, root
18	Vitellaria parodoxa	Saotaceae, Sapotacea	Kadanya	Cancer	Bark, root, leaves, seeds
19	Sanseviera spp	Moda/kabar	Giwa	Cancer	Root, leaves
20	Opuntia inermis	Cactaceae	Takalmin binta	Cancer	Whole plant
21	Amaranthus spinosus	Amaranthaceae	Zaaki banza mai kaya	Cancer	Whole plant
22	Leptadermia hastate	Asclepiadaceae	Yadiya	Cancer	Leaves, stalk, root, whole plant
23	Asparagus Africana	Liliaceae	Adamu adawa	Cancer	Bark, leaves, root
24	Acacia nilotica	Mimosaceae	Gabaruwa /kasa	Cancer	Leaves
25	Ziziphus spina chriti	Rhamnaceae	Kurna	Cancer	Leaves, bark, root
26	Annona senegalensis	Annonaceae	Gwandan daji	Cancer	Bark, stalk,

					leaves, root
27	Tamarandis indica	Caesalpiniaceae	Tsamiya	Cancer	Bark, dry fallen bark, leaves, root
28	Cassia singuena	Caesalpiniaceae	Rumfu	Cancer	Leaves and stem, root
29	Ampelocissus grantii	Vitaceae	Rogon jeji	Cancer	Root, leaves, stalk
30	Cassia siberiana	Caesalpiniaceae	Marga/ dankila	Cancer	Roots, leaves, bark
31	Senna siamea	Caesalpiniaceae	Flawan turawa	Cancer	Bark, leaves

Three of the plants showed impressive anti-cancer activities against both breast cancer and brain tumour (Figures 6 and 7). The order of relative potency is EFT20<ETF6< E T F 3. The ETF20 killed both breast cancer and brain tumour cells at a very low concentration of 12.5 ug/mL. Later, we screened the rem aining plant extracts and presented in Table 5. T hree pluses (+ ++) m eans the extract killed over 80% of the cancer cells at 250 g/m l w hile tw o pluses (+ +) represents over 80% death w ith a higher concentration of 500 g/m l.

Figure 6. Effect of Ethanol Extracts on Brain Tumour Cell Viability

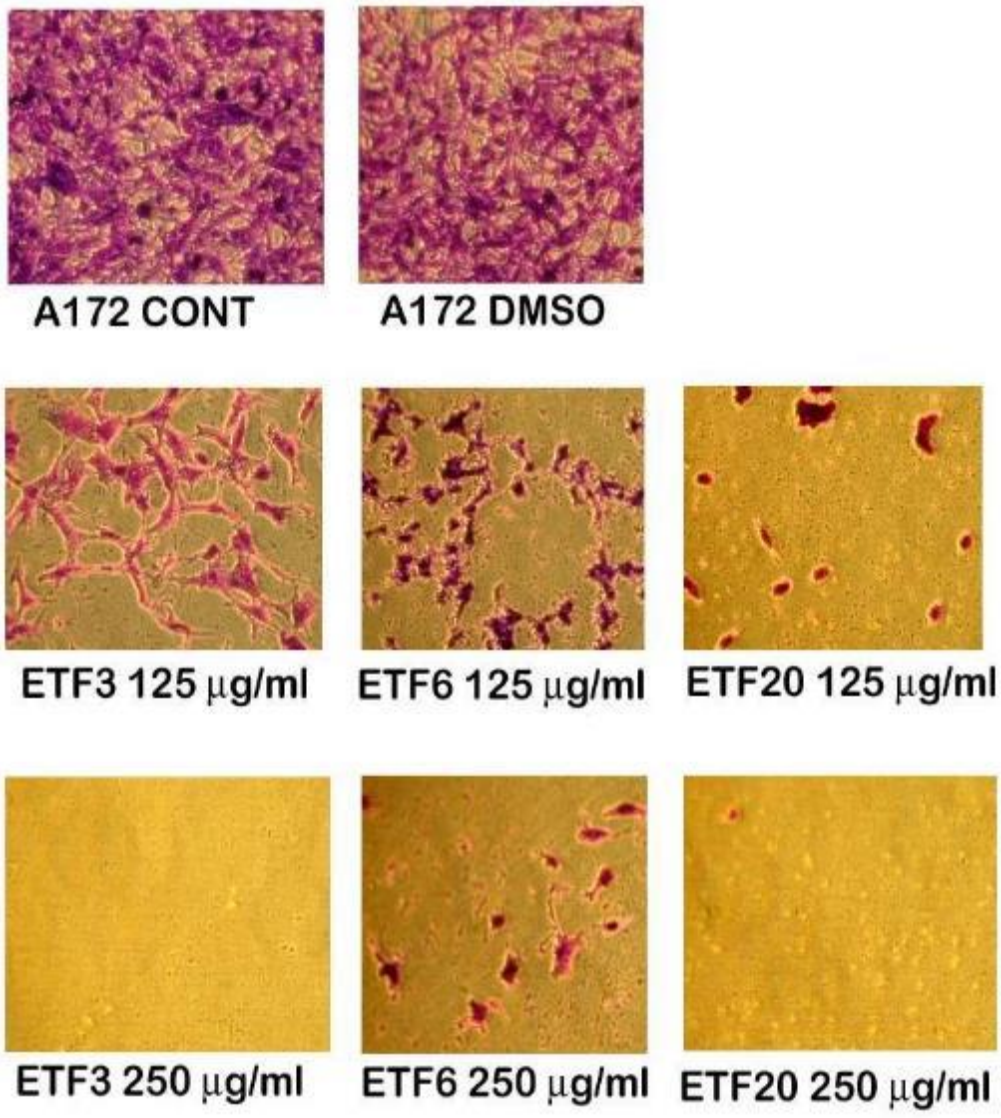
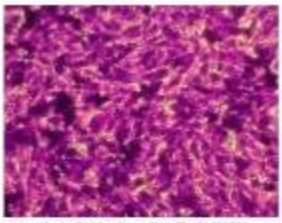
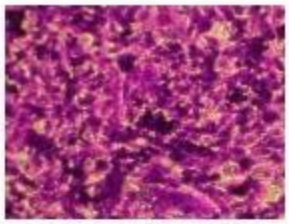


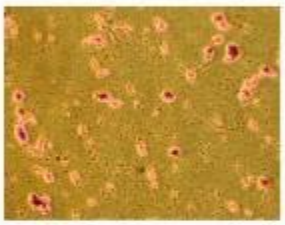
Figure 7. Effect of Ethanol Extracts on Breast Cancer Cell Viability.



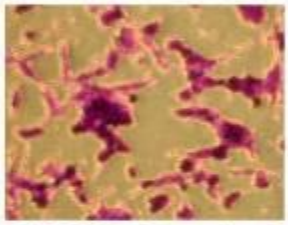
U231 CONT



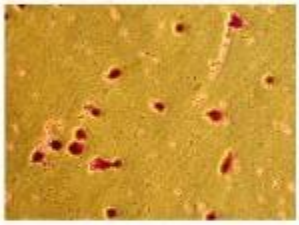
U231 DMSO



ETF3 125 μg/ml

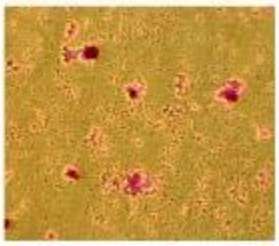


ETF6 125 μg/ml

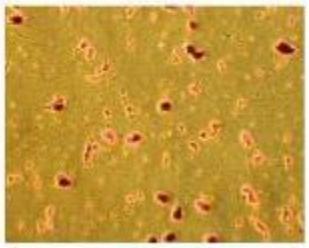


ETF20 125 μg/ml

ETF3 250 μg/ml



ETF6 250 μg/ml



ETF20 250 μg/ml

EXTRACT	BRAIN TUMOURS	BREAST CANCERS
E TF1	+	-
E TF2	-	+
E TF3	+++	+++
E TF4	-	-
E TF5	-	-
E TF6	+++	++
E TF7	-	-
E TF8	-	-
E TF10 (E A M A D 1)	-	-
E TF20 (E A M A D 2)	+++	+++
PLANT EXTRACT	**ACTIVITY AGAINST BRAIN TUMOUR**	**ACTIVITY AGAINST BREAST CANCERS**
E TF9	+++	++
E TF10	+	+
E TF11	++	++
E TF12	+++	+++
E TF13	-	-
E TF14	-	-
E TF15	-	-
E TF16	-	-
E TF17	-	+
E TF18	+	-
E TF19	+++	++

PLANT EXTRACT	ACTIVITY AGAINST BRAIN TUMOUR	ACTIVITY AGAINST BREAST CANCERS

E TF20	-	-
E TF21	-	++
E TF22	-	-
E TF23	+	+
E TF24	-	-
E TF25	-	-
E TF26	-	-
E TF27	-	-
E TF28	-	-
Z-7	+++	+
Z-9	++	-
J A -B	+++	+++
J A -C	-	++
J A -I	++	++

Current and Future Plans for Cancer Research at the University of Maiduguri

Traditional herbal medications are used extensively for the treatment of a variety of diseases including cancers in Nigeria. We will continue to use this untapped and rich source of herbal plants in combination with modern tools to provide scientific rationale for the folkloric use of these medications. The first task is to establish a robust database of all possible plants used in the former North Eastern State of Nigeria. We have increase our database to approximately 200 plants. The second phase of the project is to screen these plants for their anticancer properties using established cancer cell lines, patient cancer specimens, cancer stem cells and animal models of cancers, which will be followed by identification of active principles in the plants using mass spectrometry and NMR analyses.

The anticancer screening was carried out at the University of Virginia, Charlottesville Virginia, USA. We have now established a world-class Tissue Culture Facility for growing well-characterized cancer cell lines and primary cancers from patients. The setting up of a standard Tissue Culture Facility, dedicated laboratory for cancer research and the use of molecular techniques to investigate the underlying mechanisms for anticancer properties

of Nigerian herbal plants will place the University of Maiduguri as a Centre of Excellence for cancer research and the best Cancer Research Institution in Africa.

Challenges for Cancer Research

(1) Insecurity

(2) Inadequate Funding

(3) Unreliable power supply

(4) Lack of Institutional and Government Support

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