

**UNIVERSITY OF ILORIN**

**THE SIXTY – SEVENTH INAUGURAL LECTURE**

**MINERALS AND FOSSIL FUELS DISCOVERY: THE  
ADVENTURES OF EXPLORATION.**

By

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## **MINERALS AND FOSSIL FUELS DISCOVERY: THE ADVENTURES OF EXPLORATION:**

“ Not by might , nor by power, but by my spirit, says the Lord of Host.” Zacchariah 4: 6.

Mr. Vice Chancellor Sir,  
Deputy Vice Chancellors (Academic and Administration),  
Registrar,  
Dean, Faculty of Science: Deans of the other Faculties,  
Dean of the Postgraduate School and Student Affairs,  
Colleagues in Academics,  
Great Unilorin Students,  
Distinguished Guests,  
Ladies & Gentlemen.

### **INTRODUCTION**

I stand before you today to deliver the 67<sup>th</sup> in the series of Inaugural Lectures being organised by this great University. The lecture is historic in some ways. God Almighty has made it the second to be presented in the Department of Geology of this University but the first to be presented by a Nigerian Geologist in that Department. It is a very great honour for me to have the opportunity of telling you about some things that have been accumulating in the back of my mind for so long. A public lecture like this generally involve authors who feel obliged for some reasons to offer personal philosophies and generalities. This will not prevent me from speaking about some specifics , particularly my contributions, suggestion to solutions and partial solutions to certain problems . The topic “ Minerals and Fossil Fuels Discovery: The Adventures of Exploration “ was selected as a subject of discourse for some reasons:

- A. To enlighten the general public on the roles geoscientists play in mineral discovery ;
- B. To consider some of the processes involved;
- C. The constraints, dangers and successes;
- D. And at least create more awareness on the need for the geoscience profession.

A movie on the discovery of oil at Oloibiri in the Niger delta during a career week at my Alma mater The Baptist High School Iwo in 1966 motivated three young boys in class 4 of that school. My best friends Julius Olayinka Singerr, Julius Afolabi and I benefited from the story in this movie and then expressed our desire from that day to be geologists.

The slangs for greeting ourselves therefore changed by our admirers who then nicknamed us as “geologists in the making” . Three years thereafter, I had a singular opportunity to meet with the “Father of Geology in Nigeria” and the first African Professor of geology, Professor M.O. Oyawoye who advised that a good background

in Chemistry was very important for Geology. Luckily for me, I had the best result in Chemistry in my Cambridge Higher School Certificate examination that same year and was admitted to read Geology at the University of Ibadan. As if this was not enough, the presenter of today's lecture after bagging a Second Class Upper (Honours) degree in Geology at University of Ibadan and an MSc Geology in Canada, had another opportunity to meet Professor Oyawoye in 1977 who asked the same "Young man, what do you want to do now that you have your MSc?. I will suggest you join us and be here as a Research Fellow. Let me see what the University says, but put an application up and come back to see me in a week's time". I went back to him and the Professor said; "the University here is having some difficulties presently with new appointments, at any rate, I will suggest to you to join them in Ilorin because that place needs to grow". There and then, Professor Oyawoye collected a set of my C.V. and forwarded it to Professor Akinkugbe who within a week appointed me as a temporary Assistant Lecturer in this University.

I therefore have a great cause to salute the vision and foresight of the first Nigerian Father of Geology, Professor Oyawoye who have contributed in no small way to the initiation, development and successes of the man standing before you. May he continue to grow from strength to strength Amen.

#### 1.1. History of Mineral Resources Exploration:

Mineral resources can be equated to "Wealth"; and of all major natural resources needed for development, in terms of trade, balance of payments, foreign exchange and reserves, mineral resources play a significant role. This is the reason why the search for minerals dates back to the existence of human beings and the developed world based their growth and development on the extraction and utilization of their mineral resources. The supply of mineral raw materials is a widely discussed topic and the awareness of resources and how to explore, produce and strategically utilize them have been an unparalleled challenge for politicians, scientists and economists. These challenges include:

(a) searching for the mineral raw materials, evaluating them and producing them for commercial profit;

(b) the valuable raw materials are vigorously conserved, stockpiled, recycled to a great extent after use and substituted as far as it is economically visible.

Ideally, a nation should harness and process the natural resources within its borders through its own resilience and self efforts. This is crucial for the development of heavy industries particularly steel, petroleum refining and petrochemicals based projects. The development of these industrial elements based on modern technology is the ultimate for industrial advancement. The biggest problem faced by the mineral, oil and gas industry today is how to avert or at least lessen the impact of future mineral drought. The alarm of an impending shortage has been eloquently sounded by many and it is to be accepted that a general mineral shortage is somewhere in the horizon considering the ever growing world population being put at approximately seven (7) billion people as of today.

## 1.2. Prospecting and Early discoveries:

Bateman (1967) described mineral deposits simply as “rocks with unusual composition, resulting from geological processes”. The early prospectors though highly unskilled were extremely curious to report whatever unusual rocks occur in their environments, be it on land, lakes, rivers and various terrains. Leached outcrops, gossans, floats etc. were targets for the prospectors in search for specific minerals at or near a known site, belt or region. This has led to important discoveries. No doubt, that most ore-bodies, mineralizations, discovery outcrops were discovered by early prospectors. At the beginning of the last century and up to the middle of that century, major findings were recorded in many mineralogenic and metallogenic belts by prospectors. “Saturation prospecting” took over when companies were later set up to utilize geological knowledge for the establishments of genetic concepts, models and test them using standard tools e.g Airborne geophysics (including seismics) and litho-geochemistry.

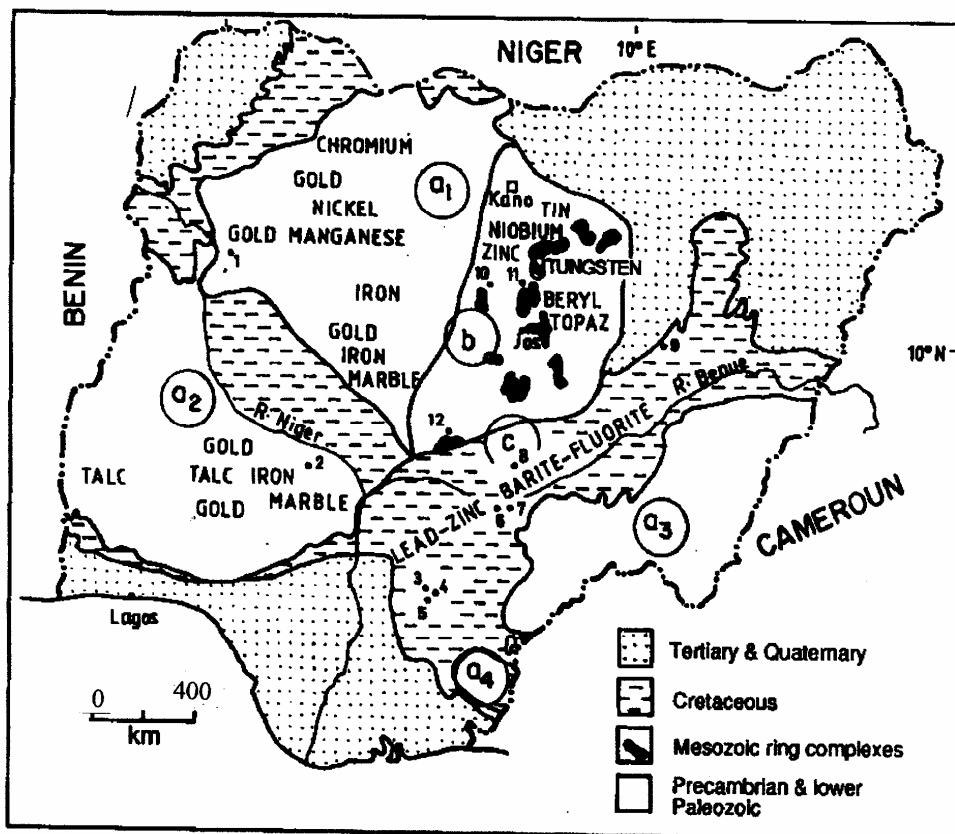


Fig. 1a Solid Mineral map based on the geological setting

Taking the USA as a case study, there is no doubt that the country has been well prospected for the past 100 years or more and prospectors have long passed away. Therefore the nation has attained a level of “Exploration Maturity” wherein new ore-bodies, new discoveries or interesting mineralization are presently difficult to come by. For the exploration and mining companies, to fulfill their responsibilities of supplying raw material needs, they must work harder.

### 1.3 Prospecting in Nigeria

Early prospectors in Nigeria discovered iron, gold, tin, tantalite in commercial quantities at the beginning of the last century. Production of gold was estimated at about 120 kilograms prior to independence (c.f. Akande et al. 1988b, Figs.1a and b).

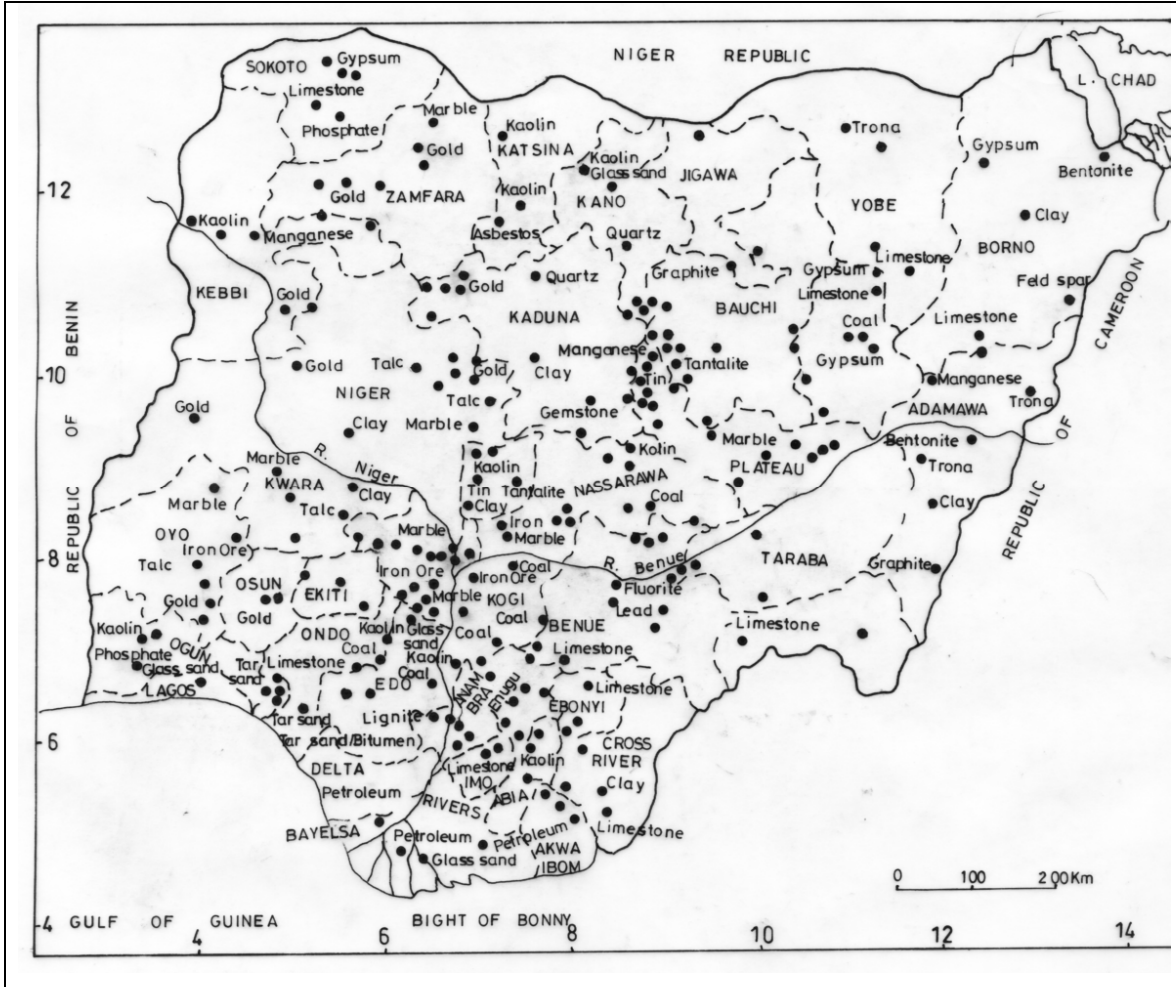


Fig.1b Overall mineral map of Nigeria based on political subdivisions.

Prospecting for oil began as far back as 1908 by the German affiliated company – The Nigerian Bitumen Company around the site of oil seepages in Araromi, south western Nigeria. Rigorous exploration began in 1937 by Shell Darcy (the former Shell Petroleum Development Company of Nigeria forerunner) who discovered oil in 1951 in commercial quantities in the Oloibiri field (Oloibiri –1 well) east of the Niger delta (Fig.1). The initial production of 5000 barrels for the year at that time has grown considerably to over 2.3 million barrels of oil per day today based on the OPEC quota allocation from a current reserve base of about 32 billion barrels of oil and 160 trillion standard cubic feet of gas. There are over 50 oil and gas exploration and producing companies in Nigeria as of today. There is the need to increase the reserve base too in view of the ever increasing

demand for foreign exchange to sustain the economy. The proposal by government is to increase the reserve base to ca. 40 billion barrels of oil by the year 2006 and seek for a

production quota of 4 million barrels of oil per day by the year 2010. This proposal if well funded by all the interested parties will put great challenges to geologists who will need to find the oil. So what started as a land prospecting adventure for hydrocarbons about a century ago now needs the relentless efforts of applying new and modern technology to find more oil. Other mineral resources like tin, columbite - tantalite, gold that Nigeria produced early in the last century had long reached the status of declination. We need to work harder to search for them and produce the economic grades needed for modern technology.

#### 1.4 Classification of mineral deposits and fossil fuels:

In general, mineral deposits derived from the earth crust and upper mantle are of immense value to man. The fossil fuels constitute important energy resources for mankind. The term solid mineral is frequently used to describe the nature of mineral deposits in terms of their hardness.

Solid mineral deposits therefore encompasses a wide variety of endowments ranging from iron ore to coal, sand and gravels, some of which are found on the surface, while others can only be won from the earth through underground mining. Two broad groups are common: Metallic minerals and Non –metallic mineral deposits. The metallic mineral group consists principally of Iron ore , Manganese , Nickel ,Tin ,Lead ,Zinc ,Aluminum ,Copper, Chromium Cadmium, Antimony, Zirconium etc.

A sub-group of metallic minerals include (a) Precious metals e.g gold, silver, platinum and platinum group metals (PGM) and fissionable metals which include uranium, thorium and radon.

The non –metallic mineral deposits are generally common substances with relatively low prices compared with metals. They are different because they can be used as a whole, require very little treatment and can be described as industrial minerals. These include ;

- (a) Structural and Building Minerals : e.g limestone, gypsum, asbestos, sand, gravel, marble , clay, feldspar, dolomite and fluorspar.
- (b) Chemical Minerals : e.g salt and other evaporites like sodium carbonate, sulfate, potash, phosphates, nitrates, sulfur
- (c) Refractory Minerals : e.g graphite, clays, kyanite, sillimanite.
- (d) Abrasives: corundum, quartz, sand, diatomite and monazite
- (e) Insulators: asbestos, micas, talc and clay varieties.

- (f) Gemstones: aquamarine, emerald, diamond, ruby, garnet, sapphire, amethyst, tourmaline, zircon and topaz.

The fossil fuels consist principally of petroleum, natural gas, coal, lignite, bitumen and tar sands. While some of the minerals are important for local industrialization and for foreign exchange revenue, others are principally used to protect the national security, national interests and enhancements of local employments and technology.

Table 1.1a Reserves of the Major Minerals in Nigeria

Source – Aribisala (1992)

Mineral	Market	Reserves	Longevity
Iron ore	Local	2.3 bill. Tonnes	-
Lead & Zinc	Local	1.5 mill. Tonnes	20 years
Cassiterite	Export	100,000 Tonnes	10 years
Barite	Local	730,000 Tonnes	-

Table 1.1b Reserves of the Major Fossil Fuels in Nigeria

Source – Adesida (2002), (Orajaka et al. 1990)

Commodity	Major Market	Reserves	Longevity
Crude Petroleum	Export	ca. 32 billion barrels	30 years
Natural Gas	Export	160 - 300 trill. std cub. ft.	100 years
Tar sands	Local / Export	40 billion barrels	Untapped
Coal (sub-bitum.)	Local / Export	1.5 billion tonnes	-
Coal (Coking)	Local / Export	128 million tonnes	-
Lignite	-	300 million tonnes	Untapped

## **2.0 MODERN PROSPECTING AND EXPLORATION TECHNIQUES.**

### 2.1 Geoscientific Information :

#### Terminologies:

Several common terminologies are important in the field of Exploration geology. Simple definitions of the most common ones are outlined as follows:

- i. Mineralization - is an unusual concentration of recognizable minerals in the crust which may or may not be economic.
- ii. Ore - is an economic mineral occurrence in the crust which from a standpoint of a miner could be mined for profit , but from the standpoint of a metallurgist could be treated for profit. The ore commonly contain ore mineral plus the gangue which is the unwanted material. Ores are described as proven, probable or possible.
- iii. Ore body - is the proven economic deposit ;this may be synonymous with a mineral deposit.
- iv. Mineral belt - a region containing several associations and varieties of mineral deposits is a mineral belt. On a larger scale, a mineral belt could be a metallogenic or mineralogenic belt or province.
- v. Host rock - is the rock enveloping the ore body.
- vi. Syngenetic ore – is an ore-body that formed simultaneously with the enveloping rocks.
- vii. Epigenetic ore – is an ore-body formed later than the enclosing rocks.
- viii. Gossans – is an oxidized and weathered mineralized rock which can be further classified as true gossans and false gossans.

Science and scientific research are the basic tools of mineral prospecting and exploration. Muessig (1979) defines Science and Exploration as follows “ Science strives for understanding: exploration strives for discovery” Without doubt, the geological understanding of mineral and energy resources and their formational environments are of fundamental importance to efficient exploitation. Hence, multidisciplinary research

programmes in institutions and the industry have these as their principal objectives. Research, applying geological, geophysical and geochemical principles have provided in-depth study of minerals, their host rocks and alteration products: also the source rocks, reservoirs, seals, and traps in the case of oil and gas.

Therefore in the training of geological principles, observations, interpretations and recordings of interpretive data lead to eventual applications. Advances in the knowledge of the structure and composition of the Earth, continental drift and plate tectonics have provided the framework for understanding the rock forming minerals and mineralization processes. Once the interpretive data set on deposits are assembled, these can be utilized as critical guides to prospecting and discovery of new deeply buried ones.

### 2.1.1 Geological Prospecting and Exploration

Before the advent of sophisticated methods, applying the physical and chemical principles to study rocks were fundamental to prospecting and exploration.

Mineral deposits are complex geologic features resulting from special sets of conditions; if not, it would be a common place in the crust. However, they are clearly not, complexities involved; vary from the oxidation state of an element in a mineral to the structural development of a mountain range. Different classes of deposits e.g the “roll front” Uranium mineralization milieu is clearly different from the environment for bauxite deposits which is also different from that of the porphyry type copper – molybdenum environments. Therefore the complexities of the different geologic environments have to be characterized and applied to the knowledge of the search for ores. Similarly in the case of fossil fuels, the different sedimentary environments for coals, e.g lignite, bituminous and hard coals of different ranks have their geologic peculiarities compared with hydrocarbon reservoir environments.

Geologic prospection of the different mineral groups will therefore entail adequate assemblage of data sets including appropriate maps, sections, logs, etc. from which the geologic history of the area of interest could be interpreted. Suffice to say that geologic maps and rock sections have no substitute as tools for mineral discovery and there will never be. The basic geology must come first and if this is wrong, every other thing that follows will be wrong. It is fundamental that a geologic model that is not only descriptive be provided. This must provide genetic information. The basic geology therefore will serve as the basis for a meaningful adventure. Some of the geological guides for discovery in an area of interest may include evidence for wall rock alteration (i.e host rock alteration), mineral zoning, structural relations and stratigraphic controls.

The geologist needs to have adequate knowledge of what these evidences are and how they can be displayed on the rocks, in the rocks or within the rock record. The usage of some of these geological guides in known mineral belts e.g the copper districts in Arizona, USA , Noranda in Quebec, Canada have led to billion dollar finds in the middle of the last century.

### 2.1.2 Geophysical Prospecting and Exploration

The basic physical properties of rocks are utilised in geophysical prospecting and exploration. Based on this premise, several geophysical methods particularly magnetics,

gravity, resistivity, induced polarization and seismics have been applied in mineral exploration and exploitation. The method used, depends on the type of resources to be investigated. While magnetics is adequate for the search of iron ores and induced polarization is frequently applied for the search for disseminated copper mineralization in intrusive rocks, the preference for oil and gas exploration is seismics. These methods have developed considerably and now form specific fields of their own in modern prospecting. Indeed, most exploration system will drill wells only after adequate geophysical data have been acquired. This applies to both solid minerals and oil and gas upstream.

Advancement in the geophysical methods have led to the integration of borehole geophysics in assaying, development and production. It is therefore a common activity to carry out electrical logging using spontaneous potential, resistivity and electromagnetic responses of the lithologies penetrated in a well or other logging techniques e.g radioactive logging, gravity logging, magnetic logging, etc. to assemble all the physical characteristics of relevance to exploration and exploitation of the wells drilled. The geophysical prospecting techniques are therefore very well developed on the basis of modern technology.

In oil and gas exploration, most discoveries have been made through the initial 2D seismic data acquisition in the middle of the last century (e.g in our own Niger delta basin). The advancement into 3D seismics data acquisition has led to more discoveries of by-passed oil in the latter part of the century and the newly developed 4D seismics will be instrumental to better recoveries in the old and newly drilled oil wells of the future.

### 2.1.3 Geochemical Prospecting and Exploration

The application of geochemical principles to prospecting and application emerge from the knowledge of associated mineral assemblages in ore –deposits, their elemental associations and dispersions of the elements in the crust. Mineralogical studies of ore deposits suggest the possible elemental associations expected and these have formed the basis for the identification of primary and secondary dispersions that commonly serve as pathfinders for ore bodies.

The chances that most of the ore deposits that are close to the surface have been discovered is very high. Therefore, chances for new discovery depend on the depth of penetration of the technique. In this circumstance, geochemical exploration successes have been remarkable in countries like Canada, U.S.A, Australia and South Africa in the second half of the last century where chemical composition of drill cores from buried rocks are frequently analysed.

The principles applied involve the mapping out of primary halos which are syngenetic with the mineralization and secondary halos which are epigenetic with the mineralization. The question is to identify what you need to measure in relation to the principal target. For instance, single element concentrations e.g Hg, Te anomalies can serve as pathfinders for porphyry copper and molybdenum deposits ; Zn and Tl anomalies can serve as pathfinders for stratabound Pb – Zn deposits. Multi-element halos can exist around ore-bodies e.g Na<sub>2</sub>O – Sr, TiO<sub>2</sub> – Cr –V are pathfinders for the volcanogenic Cu –Pb –Zn deposits in the Woodlawn district of Australia where dispersions are identifiable up to 2 km from the ore-bodies.

Trace elements in separate mineral phases e.g Tin contents in the mineral – biotite can assist in the search for tin deposits while others e.g Co / Ni ratios in pyrite can distinguish the pyrites near ore-bodies from the syn-diagenetic pyrite. Similarly, Sn and Bi anomalies can outline true gossans of copper and zinc deposits as discriminants for false gossans which occurrence may be misleading.

Primary and secondary halos have therefore assisted in finding ore deposits that are buried at great depth by in-depth sampling of rocks, drill cores from drill holes, stream sediments etc. The deepest ore deposit discovered with geochemistry is the Red Mountain copper porphyry deposits in Arizona at a depth of 1000m by geochemical halos (c.f Wellmer, 1982). This suggests that the hunt in this century will be for blind deposits that are still buried beneath thick blankets of surface rock. Integrated mapping in the third dimension will form an important background work through the use of deep seismic sounding, lithoprobe, deep continental drilling and drill core geochemical analysis. Exploration geologists of the future may need to map the earth crust to depths of 15 – 20km to discover blind ore deposits.

The use of measurements of the concentrations of stable and immobile elements e.g Zr, Ti, Nb, Y, Cs, Ga, Se, have identified the proximity of felsic volcanic rocks which are most favourable for volcanogenic massive sulfide deposits of copper, lead and zinc in older PreCambrian greenstone terrains (Thurston, 1981).

The use of stable isotope composition of mineral phases in the rocks e.g. sulfur, carbon, oxygen, lead, strontium, neodymium, samarium has been especially helpful in identifying the source of fluids characterizing the geochemical environments and temperature of formation of the ore-bodies. All these have assisted exploration as the emerging technology has applied the techniques of geochemical prospecting in exploration. Lead, strontium, neodymium and samarium isotope studies have aided the determination of the age of mineral formation while fluid inclusion microthermometric studies in minerals have provided evidence for the nature, temperature and composition of fluids responsible for the formation of ores.

The application of these outlined geochemical principles has been greatly advanced for mineral prospecting and exploitation to such a level that Badejoko (1995) described Geochemistry as the “Heartbeat of Mineral Resources”. I fully concur with this remark and I know that future exploration successes will be based on the refinements and integration of these principles in ore – deposits genetic models.

## 2.2 Formulation of Geologic Models

Modern exploration practice normally involves the application of geologic models. A geological model in the simple sense is a mental process of interpreting the origin of mineral deposits. This involves adequate and acceptable explanation of the processes that gave rise to mineral deposits. A model that is developed for any exploration work will establish all the vectors by which the presence and location of hidden mineralization could be recognized. Models cannot be rigid, it must be flexible, workable and dynamic. In view of the ever-growing need to apply workable models to finding hidden resources, the science of exploration if applied, can provide adequate evaluation of resources, in an area of interest. During surface mapping and exploratory drilling, models are constantly

modified until it is proven to be a satisfactory one. In any exploration campaign, one must have a model in mind and this model must be a valid one. Therefore the development of a model is of prime importance in that the geological characteristics and data-in-built must be reflected in the model. For instance the search for phosphates, reached its peak in the 1970s when its role in Agriculture as fertilizer was emphasized in order to feed the ever-increasing world population. The large discovery of phosphates principally in marine sedimentary rocks and development of a working model involving ancient seaways and phosphate accumulations relations, led to the increase of phosphate reserves of the world from 85 million tons in 1970 to 136 million tons in 1980 and up to 71 billion tons about a decade ago, corresponding to a static life time of 500 years. Models are thus developed to explain the source, transport and deposition of mineral resources and also to explain the source, migration and reservoirs of hydrocarbons.

## Existing Models

### 2.2.1 Model for the search of volcanic associated mineral deposits:

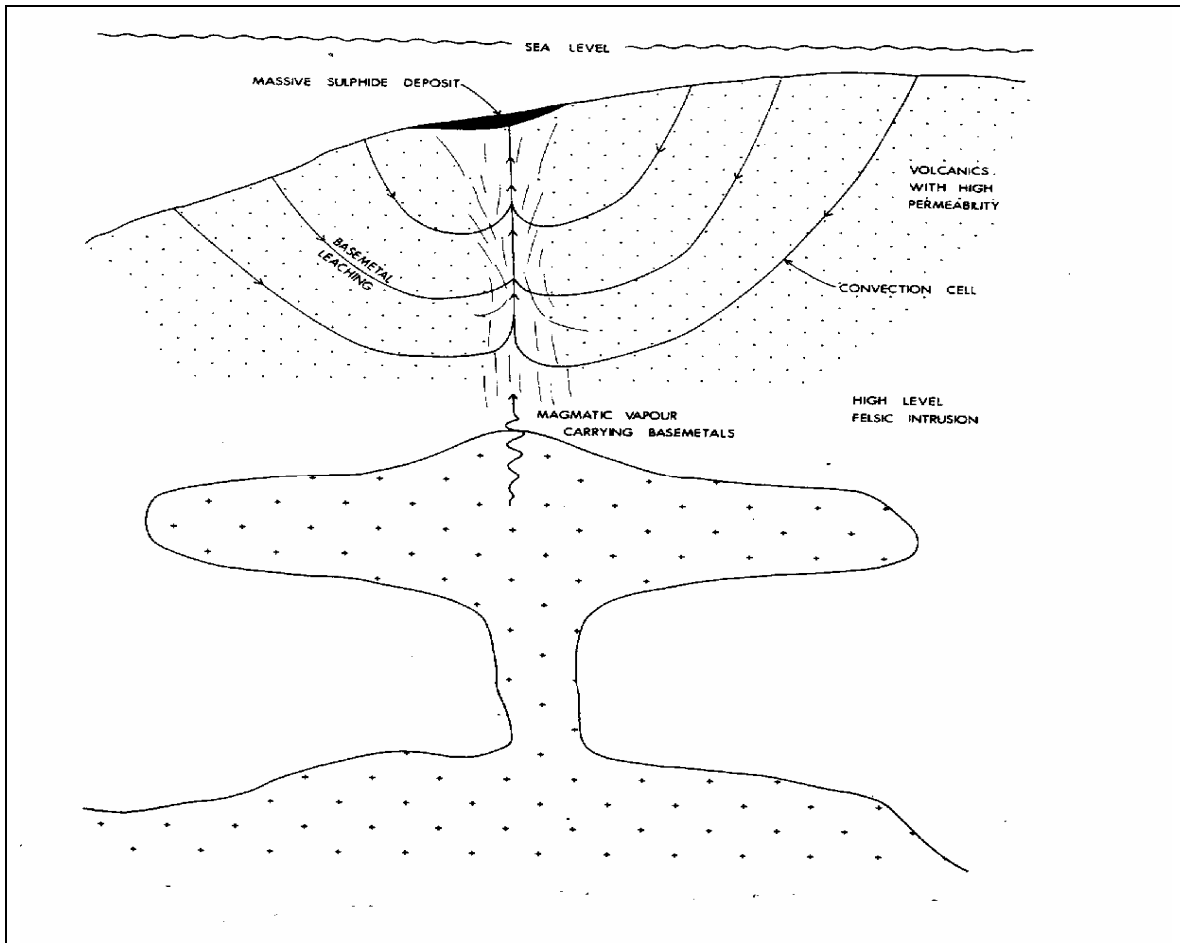


Fig. 2 Model for an active hydrothermal system precipitating massive sulfide deposits of copper, lead, zinc +- gold and silver on the sea floor. Source of metals include the volcanic host rocks and the high level intrusives (modified from Welmer, 1982)

Adventures during the search for important base metals of copper, lead, zinc, associated with gold and silver have shown that such deposits are commonly associated with 1. PreCambrian greenstone belts of the world as in Canada, South Africa and Australia where they are found in volcanic rocks; 2. Tertiary volcanic rocks e.g. the green tuff volcanics in Japan and Spain; 3. Ophiolite complexes e.g in Cyprus volcanic successions . Such deposits were discovered with the conventional prospecting techniques between 1910 – 1950. Since the second half of the last century, integrated geological , geophysical and litho-geochemistry have been adopted to develop working models. The model involved have identified the important source, transport mechanisms, depositional characteristics and environments of the ore bodies. Working guidelines from the model now include the search for :

- (a) Submarine volcanic rocks, (Fig.2)
- (b) Sub-volcanic intrusions accompanying felsic rocks,
- (c) Altered volcanic strata and
- (d) Faults, fault breccia and fault plain alteration

All of these components have played active roles in the processes involved and location of the mineral deposits at the sites of discoveries. The applications of this model have led to discoveries of several base metal deposits in Canada e.g. Noranda mining camps; Burchans, Newfoundland and several mines in the Bathurst mining district, Canada.

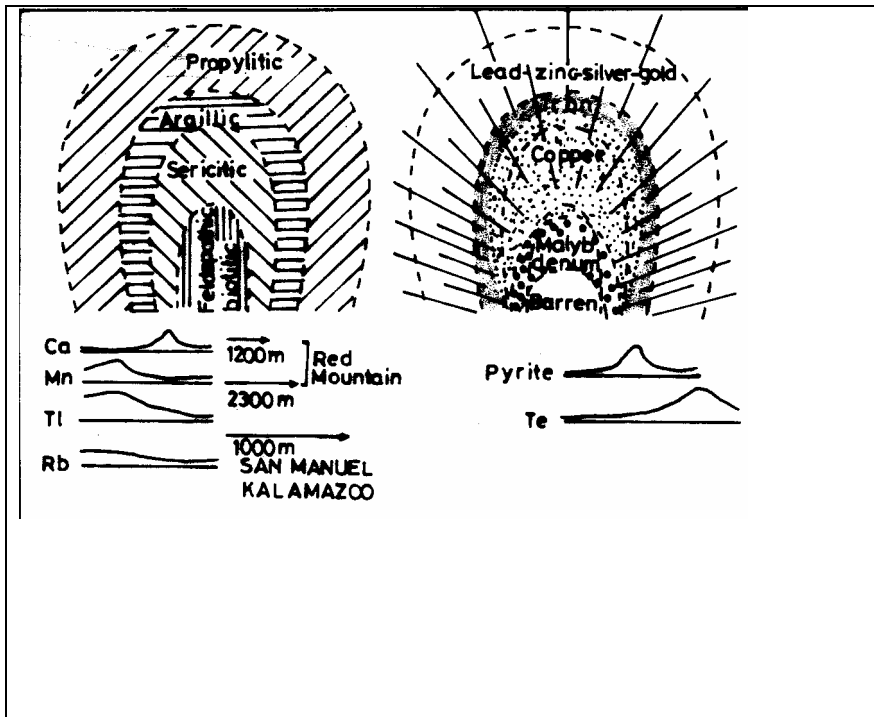


Fig. 3 Hypothetical model for the formation of porphyry copper –molybdenum deposits indicating alteration and mineralization zoning ( modified from Wellmer, 1982 ).

## Porphyry Copper – Molybdenum deposits

For this group of deposits, the importance of composite multiple intrusions have been emphasized in the working model. All members of porphyry type deposits are chemically and mineralogically identical, the only distinction being the structural habit and minor differences in texture, degree of alteration and mineralization. The ore-bodies are therefore part of composite intrusions which are spatially and coaxially arranged around the alteration types (Fig.3). The geological model for porphyry group of deposits was tested as far back as 1965 when the deep discovery of the Kalamazoo copper porphyry in Arizona was discovered at a depth of 750m as a downfaulted segment of the San Manuel orebody (Lowell 1968). Also based on geological model, the Henderson molybdenum porphyry deposit in Colorado was discovered at a depth of 1000m as a downfaulted segment down-dip of the Urad ore-body (Wallace, 1974) (Fig.4) within composite multiple stocks of rhyolitic composition.

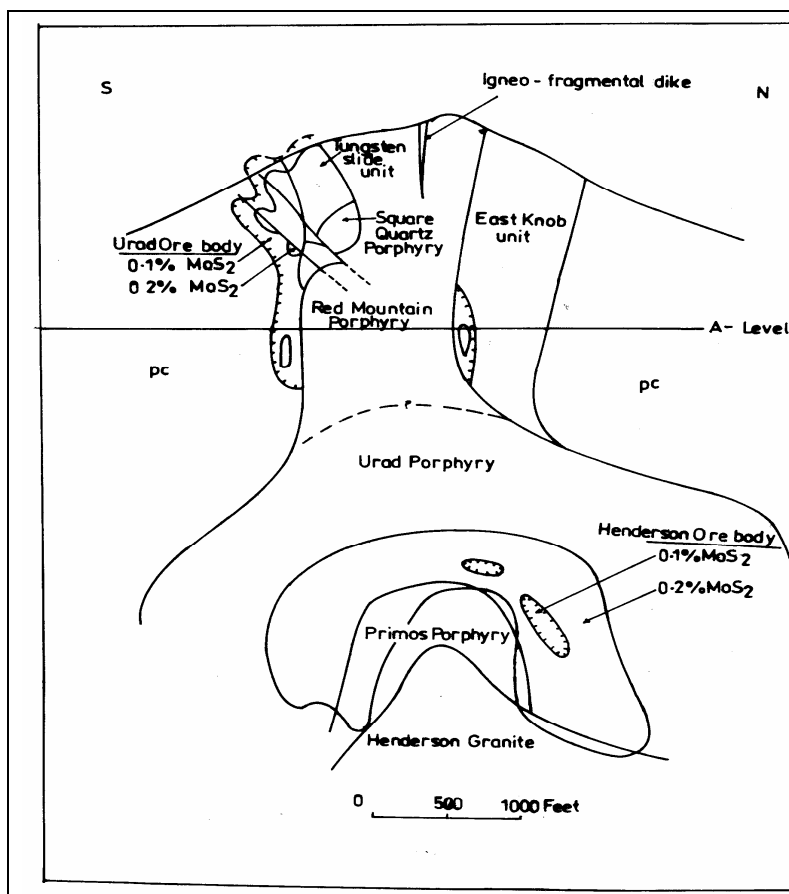


Fig. 4. Section through the Urad –Henderson orebodies; the Henderson mineralization is a down-dropped equivalent of the Urad orebody within the Red Mountain intrusive complex (from Wallace, 1974)

### 2.2.3 Gold deposits

Significant primary gold deposits occur as veins, lodes and in shear zones apart from the great placer deposits of South Africa. These primary occurrences could be found in any type of rocks – igneous, sedimentary or metamorphic. A geological model was difficult initially and most exploration methods were based on empirical and spatial relationships with specific host rocks.

Geological models in the latter half of the last century focused on the types of fluids, temperature, transport mechanism leading to the precipitation of the gold. The model needed therefore to explain the evidence for fluids with high CO<sub>2</sub> content at temperatures of 400°C discovered in fluid inclusions and the persistent discoveries of primary deposits (e.g. veins, lodes) in faults. Based on these evidence, an acceptable model involving the epigenetic emplacement for the gold has been put forward. Guides for gold exploration now involve the search for faults, fractures and intrusions (e.g. syenites and granodiorite stocks) alteration types in the rocks e.g. silicification, chloritization and epidotization related to mineralization. New discoveries of gold deposits were reported in the 1980s especially in the greenstone belts of Canada, South Africa, Australia and Ghana, based on this working model. The recent model has therefore carried the search for gold in particular rock types e.g. volcanic and igneous intrusions as was the case in the early part of the last century (Emmons, 1937), (Lindgren,1933) to the search for specific characteristics inherent in known gold ore-bodies.

### 2.2.4 Lead - Zinc –Barite –Fluorite deposits

The frequent association of this category of mineral deposits with sedimentary rocks , most especially limestones, dolostones and occasionally in sandstones constrained their search to sediments, thereby invoking a sedimentary geological model. Such deposits are classified as epithermal i.e formed at very shallow depths of less than 3 kilometers from the surface. Major discoveries in the Virbunum trend lead-zinc belt of south east Missouri, USA were made in the middle part of the last century from the experience gained in the previously worked Old Lead belt on the flanks of the St. Francois mountains. Deposits of lead and zinc in sedimentary successions have also been found in Ireland (the Navan, and Silvermines deposits) ; in Algeria, Tunisia and also in Nigeria ( Benue lead –zinc ores). Geology and geochemical data have constrained the working models for this group of deposits and favorable environments for potential ore bodies have been outlined.

### 2.2.5 Fossil Fuels

Similar to the last group of mineral deposits i.e. the lead –zinc – fluorite ore deposits in sedimentary succession are the fossil fuel (e.g. coal, bitumen, petroleum and natural gas). These are resources in sedimentary rocks e.g. sandstone, limestone, and conglomerate reservoirs of the sedimentary basins. Basinal studies normally involve geology, geophysics and geochemical approaches. From all these, any working model will involve constraining the sources, migration, reservoir, traps and seals potentials in the case of

hydrocarbons, deposition and burial history of the sediments in both the search for hydrocarbons and coals. The above listed parameters will constrain the basin of interest as to the potentials.

### **3. MY CONTRIBUTIONS:**

Techniques involved.

Mr. Vice Chancellor Sir, I will now highlight some of my contributions in the adventures of exploration as related to exploration for minerals and fossils fuels.

My early adventure emerges from my curiosity to examine rocks of different colors, textures and hardness. Whenever I work on the hard massive rock on which cassava, melons, pepper are spread for dryness on the way to and back from schools as a young high school pupil, I had become familiar with the fact that the hard rock constituents have several colours ranging from white, pink, black, green and red. Little did I know of the economic utilization of the constituents, that precious metal like gold, silver, tin may be in those rocks used for drying food crops.

Since my involvement in detailed research into both hard and soft rocks, my scientific investigations have involved the use of geology, sedimentology, mineralogy, fluid inclusion geothermometry, geobarometry, and exploration geochemistry (inorganic, organic, and isotope geochemistry) techniques in constraining exploration models. These tools have assisted me to accumulate data, which were contributed to the exploration models for gold mineralization, lead-zinc, barite, fluorite mineralization, coal and lignite and exploration of petroleum in selected geologic environments.

Mr. Vice Chancellor Sir, I will take you through my adventure in these fields to highlight my contributions and the geological successes.

#### **3.1 Gold mineralization**

My first area of research as an independent geologist was in gold investigations carried out as a member of a team of gold geologists working out at the northern part of Canada for the M.Sc degree.

##### **3.1.1 Vein type gold mineralization in the Timmins areas, Canada.**

The so-called Canadian Shield (Fig.5), is a geological terrain with high potential for gold mineralization. Multiple genetic hypothesis were being tested in the middle 70's to confirm a workable model for gold mineralization when gold price increased rapidly from \$35 an ounce to almost \$1000 therefore causing a tremendous gold rush. My detailed geological mapping and geochemical analysis of the rocks in one of the Canadian gold mines; i.e the Ross mines between 1975 – 1977 showed that the major ore zones is a metalliferous siliceous chemical sediment which components were leached from underlying volcanic rocks by convecting sea water and subsequently deposited on the sea floor between extrusion of flows and pyroclastic rocks (Akande 1977,1982} . The primary syngenetic and stratabound vein materials were subsequently redistributed into dilatant fractures during regional metamorphism (of green schist rank) to form discordant

veins. My study of the Ross mine was a part of a larger study on which the syngenetic “exhalite “model for gold exploration was propagated for the whole of the Abitibi green stone belt gold mineralization between the middle 70’s and 80’s and the adventure also fetched me a summer job in the summer of 1979 when I was employed for a team mandated to map out “exhalites “ and exhalative horizons within the Rouyn –Noranda property of the Newmont Exploration Company.

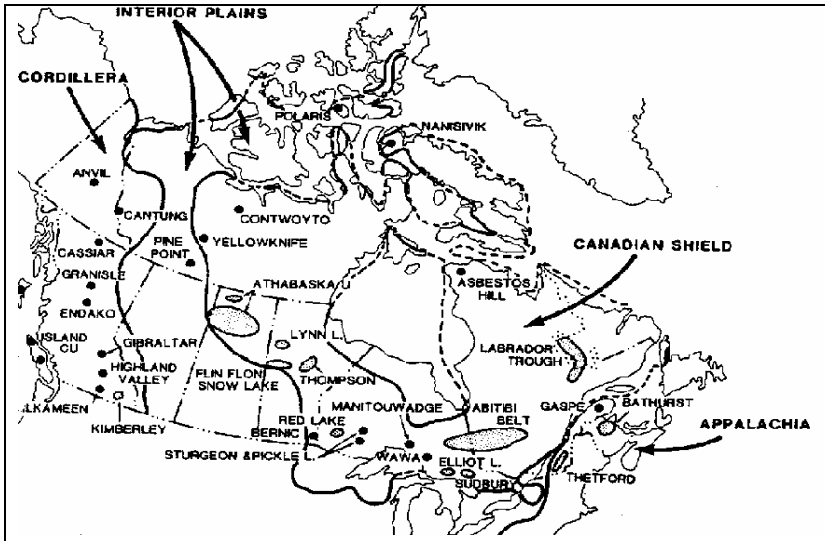


Fig. 5. Principal mining districts of Canada; outlined areas and individual dots may have more than one deposit usually of a single type ( modified from Wellmer, 1982).

### 3.1.2 Vein type gold mineralization in the Okolom and Bin Yauri areas of Nigeria.

The Canadian Abitibi greenstone adventure was extended into Nigeria during the investigation for the Okolom and Bin Yauri gold mineralization . The geological and geochemical characteristics of rocks in these Nigerian examples showed that gold mineralization in the Nigerian schist belts, have no lithologic preference and were formed during the waning stages of the Pan African thermo-tectonic events ca. 500Ma from CO<sub>2</sub> bearing ore fluids at temperatures between 170°C to 350°C (Akande et al. 1988b; Garba & Akande, 1992). The exploration model for this variety of mineralization as constructed from the data set involved metamorphic dewatering and devolatilization (Akande et al. 1988b). The gold bearing veins formed between 5 –10km depth before uplift (Akande et al. 1988b). Exploration for gold prospects should therefore document the peculiarities involved in this model for testing the potentials or worth of interest.

### 3.2. Lead –Zinc Barite Fluorite Mineralization.

Base metals of lead and zinc are important commodities for several manufacturing industries including vehicle batteries and car manufacturing plants. The industrial minerals like barite and fluorite are very important in the petroleum and metallurgical industries respectively. My contribution to exploration for this category of deposits dates back to the early 80<sup>s</sup> when my work proved that lead –zinc –barite –fluorite ore deposits

represent an integral part of sedimentary basin evolution and strategies for exploring them must take into account the pertinent source rocks, transporting medium, precipitation mechanism and preservation mode. Based on the results integrating geology, fluid inclusion microthermometry and isotope geochemical characteristics, a working model was developed and tested around some lead –zinc ore deposits which I will like to briefly consider ; The Gays River lead –zinc deposit in Nova Scotia , Canada and the lead –zinc-barite –fluorite deposits of the Benue Valley of Nigeria (Figs.6 & 7 ).

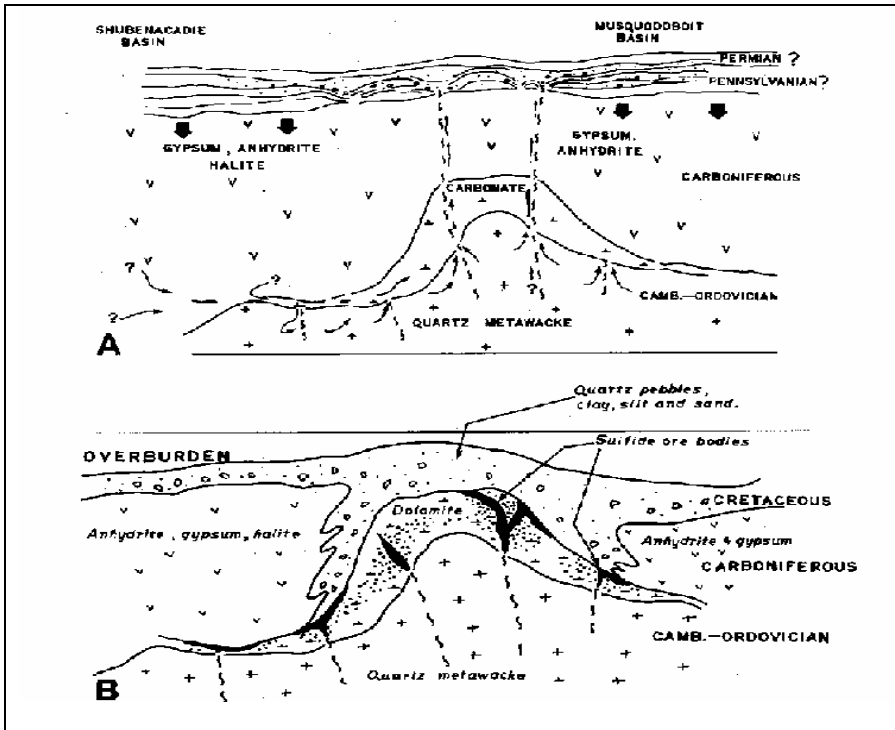


Fig. 6; a. Hypothetical model for the Gays River lead –zinc mineralization, Nova Scotia Canada. Late Paleozoic hot solutions leached metals from the metamorphic basement, follow fractures, mineralize the porous carbonate bank , breach the impermeable evaporite cap in places thereby mineralizing rocks higher up in succession; b. Preservation in the present day geological context ( from Akande and Zentilli, 1984).

### 3.2.1 Gays River lead –zinc deposits, Nova Scotia, Canada.

The Gays River deposit in central mainland Nova Scotia hosts a 12 million tonnes 7% combined zinc and lead . This deposit operated between 1975 and 1980 when it was closed down due to mining difficulties. Studies carried out by myself between 1979 and 1982 on the geology, mineralogy, microthermometric and isotope data developed into a model which favored an epigenetic process involving deeply circulating metal bearing brines from which the zinc ,lead, barite fluorite and calcite were precipitated in fracture controlled feeder systems into the carbonate host rocks (Akande and Zentilli, 1982, 1983, 1984, Fig. 6). This interpretation was the basis for designing new strategies for exploring the ore-zone and I am happy to report that the results of my adventures from rigorous field and underground mapping, laboratory work and construction of a model and putting

the model to test, led to the reopening and reactivation of the mine again in 1989 and the Gays River is currently a producer.

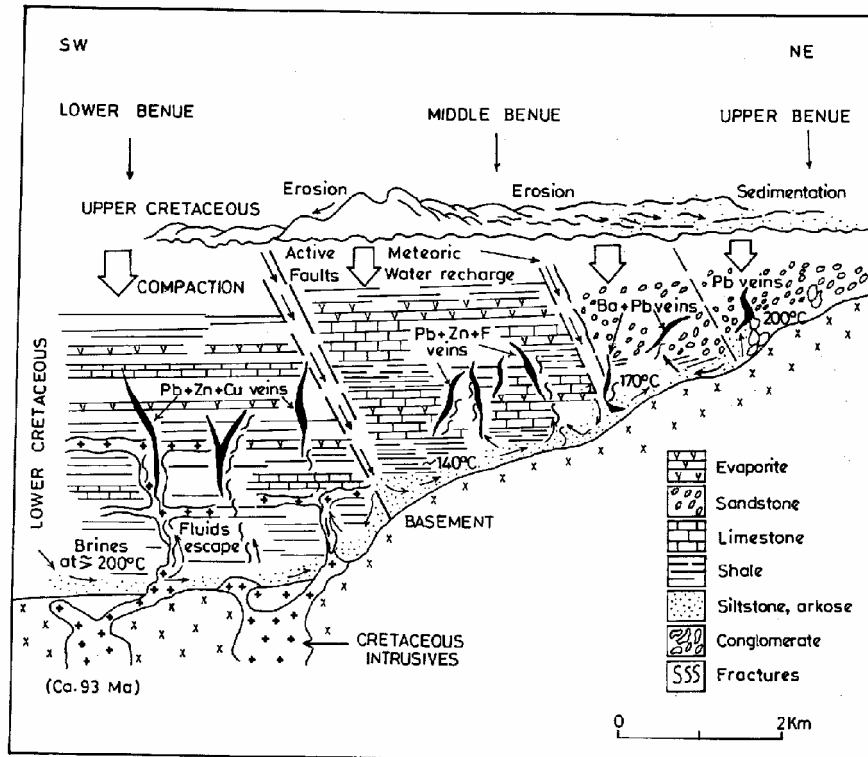


Fig. 7 Genetic model for the evolution of the lead –zinc copper –barite deposits in the Nigerian Benue Trough. Hot basinal fluids leached metals from arkosic sediments and later precipitated them as metal sulfides in Cenomanian fractures of the Asu River Group ( From Akande et al. 1989).

### 3.2.2 Lead –zinc- barite –fluorite deposits in the Benue Trough of Nigeria.

My Canadian experience was applied to studying similar deposits in the Nigeria Benue Trough. Here the study by Akande’s team since 1984 has documented the characteristics and potentials of this type of mineralization (Akande and Abimbola, 1987; Akande & Mucke, 1989 ;Akande, Reynolds and Zentilli, 1989).

Based on our studies of the geology, mineralogy, microthermometry and isotope geochemistry , the Nigeria deposits have been compared with similar deposits in USA, Canada, Ireland, and a working model was advanced (Akande, Zentilli and Reynolds 1989 ; Akande, Hoffknecht and Erdtmann, 1992) advocating for deeply circulating basinal brines which penetrated the basement for the origin of the metals. The model interpretes the Nigerian deposits in the Abakaliki, Ishiagu, Arufu –Akwana, Gombe and Zurak districts as distinct epigenetic ore bodies controlled by fractures which were formed about ninety (90) million years ago. The model suggests that the primary ore target should be the Asu River Group sediments in which the metal ore bodies are stratabound. Future exploration of this category should focus on the oldest Asu River Group sediments and lateral equivalents in the Nigerian BenueTrough. It is worth noting

that recent exploration efforts around Abakaliki in the Ebonyi State have outlined at least 2 million tonnes of lead and zinc ores based on the model put forward and indeed similar mineralization have been reported below the basement / sediment unconformity - thus proving this model to be absolutely correct (Fig.7).

### 3.3 Fossil Fuels

My adventures into this category of deposits which include the energy resources of coal, lignite and petroleum developed from the obvious associations of these deposits in similar sedimentary environments hosting especially the aforementioned base metals of lead, zinc, barite and fluorite. Fossil fuels are particularly restricted to sedimentary successions and the search for hydrocarbons and coal is principally in sedimentary rocks. While base metals occurrence in sediments represents an integral part of a sedimentary basin evolution, the thermal and burial history of any sedimentary basin are important factors in the generation and accumulation of hydrocarbons and coals provided there are potential source rocks. The consequence of overlap in this interesting associations of fossil fuels with sediments developed my interest in the research into fossil fuels and has been a great adventure. Mr. Vice- Chancellor Sir, I will talk on three specific areas where I have been involved in the adventures of fossil fuels especially in Nigeria.

#### 3.3.1 Coal and Lignite deposits in Enugu, Okaba and Orukpa area of Nigeria.

My research work on the depositional environments, diagenesis and thermal maturation of sedimentary successions in Nigeria during the course of developing models for base metals exploration was extended into the investigations of fossil fuel resources in southern Nigeria. Reflections of previous thermal studies (Akande, Hoffknecht and Erdtmann 1992a) suggest that the temperatures of formation of minerals at the lower stratigraphic interval of the Lower Cretaceous (i.e. Albian) and the maturation of sediments at that level will constrain the type of hydrocarbons that could be present.

From an extensive study of the geology, petrographic composition and ranks of coals in the Nigerian coal belt, the present author and his team established that coals in the Anambra basin have ranks which decrease from sub-bituminous A to B and finally to C grades from the Enugu area towards Okaba in the northern part of the coal belt. (Akande, Hoffknecht and Erdtmann, 1992a, 1992b, Akande 2002). In addition, it was established that the coals in the Enugu Onyeama mine is suitable for liquefaction (i.e. for conversion to liquid fuels) whereas the Onyeama, Orukpa and Okaba though non- coking , satisfies the optimum conditions for combustion, thus suggesting that the abundant coal resources in Nigeria should be exploited for more revenues (Fig.8 ).

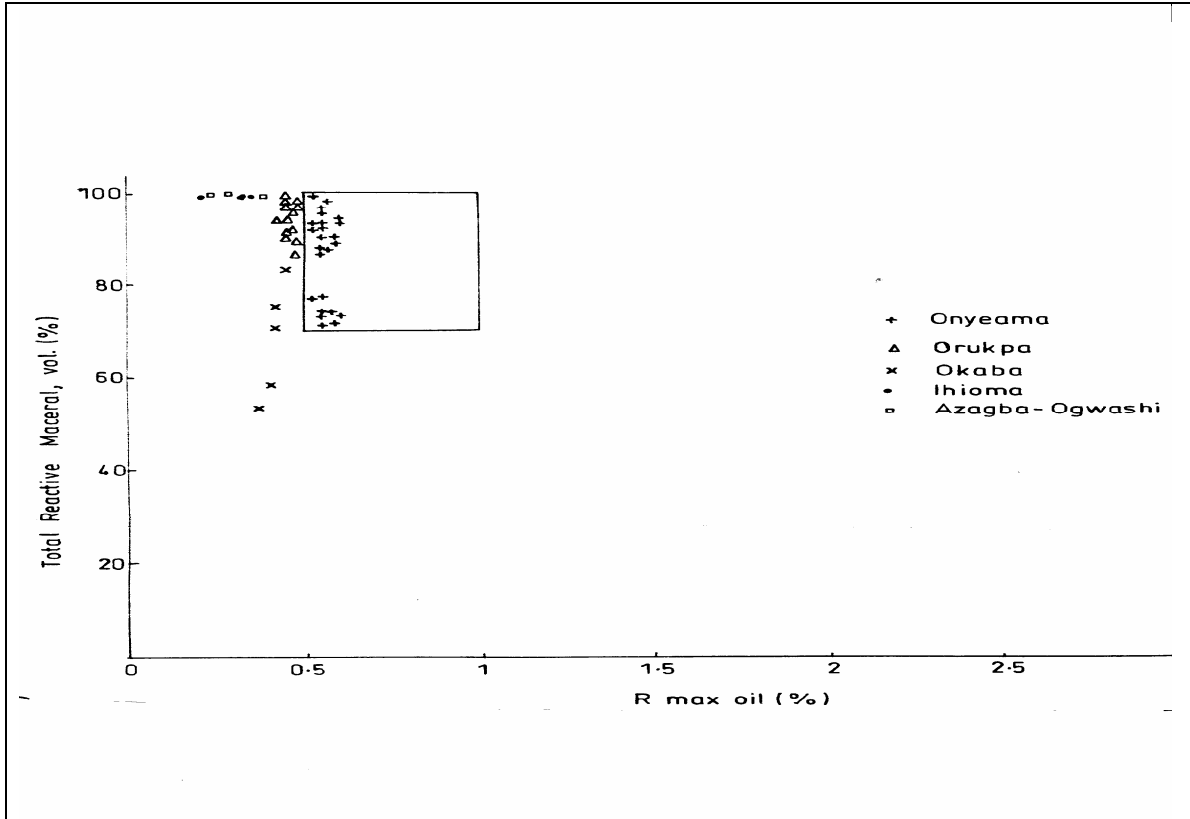


Fig.8. Liquefaction potential of the Nigerian brown coals based on ranks and petrographic composition ( from Akande, 2002).

### 3.3.2 Petroleum potentials of the Nigeria sedimentary Basins (Figs. 9 & 10)

Our accumulated adventures in the Nigerian Benue Trough and adjacent sedimentary basins have documented the potentials for liquid and gaseous hydrocarbons in addition to the prolific Niger delta basin oil and gas province. I need to emphasize that my team was a part of the active group involved in the continuous search for hydrocarbons in the lower, middle and upper Benue Trough, the Anambra basin and the Lokoja basins.

#### a) Petroleum potentials of the Benue Trough

Through a rigorous exploration adventures into the unknown and untested part of the middle and upper BenueTrough, we found the potential source rocks for hydrocarbons in the Gongola and Yola basins in the reported work of Akande, Ojo, Erdtmann and Hetenyi, 1998). Although the likelihood of petroleum accumulation is still being tested by several oil and gas companies, I was happy to be part of the early adventures of hydrocarbon search in that part of Nigeria and research have continued to identify the relations between hydrocarbons and mineralization in this region (Akande, 2000 , Akande 2001) (Figs.9 &10) ).

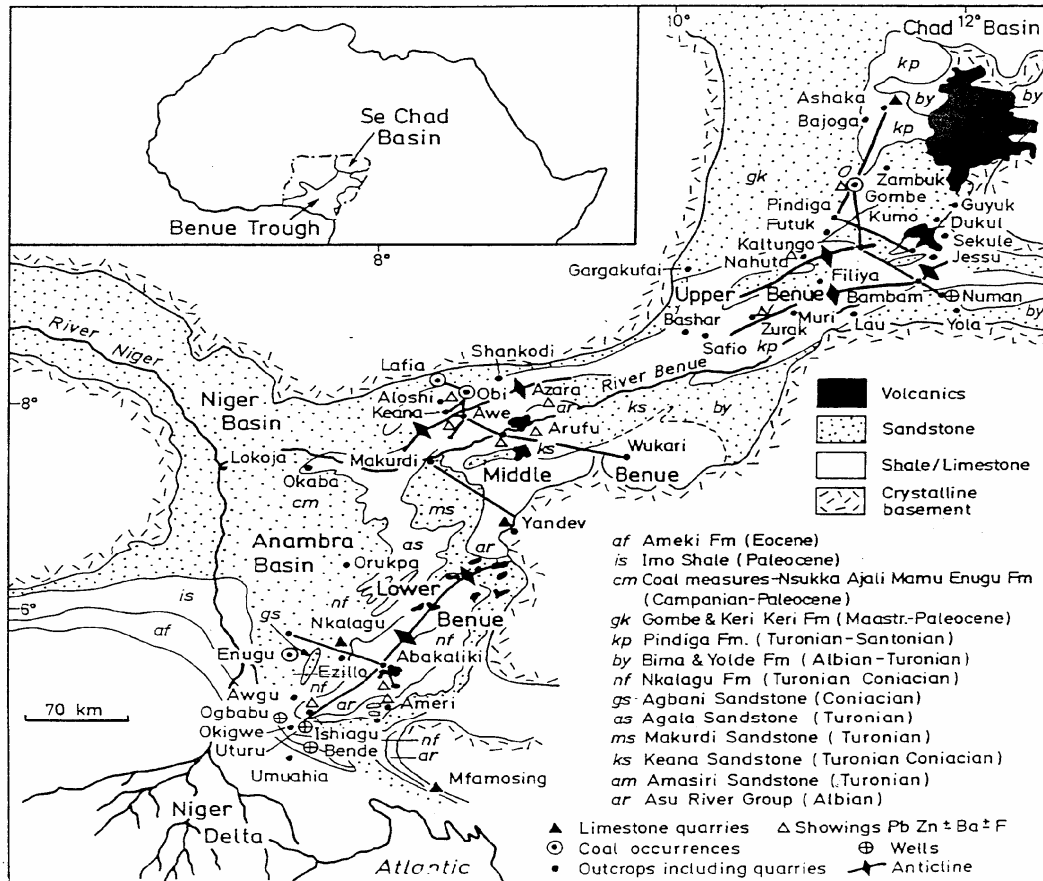


Fig. 9. Geological map of the Benue Trough showing the principal traverses investigated in the lower, middle and upper Benue regions (from Akande, 2000).

(b) Petroleum potential of the Anambra Basin

The Anambra basin represents a part of the Benue Trough mega-structure. This basin produces oil and gas because of the presence of the necessary source rocks, reservoir and trapping conditions and an estimated oil potential of ca. 1 billion barrels of oil with additional accumulation of about 30 trillion cubic feet of gas have been reported (Dublin –Green and Agha, 1999).

Despite these estimations, several unknowns still remain in respect of the main hydrocarbon source rocks, their level of maturity and the principal hydrocarbon reservoirs. Several studies of thermal maturation and source rock evaluation by my team have outlined the levels and the main sequences that are most favourable for

prospecting and exploration for hydrocarbons in this basin(Fig.11; Akande and Viczian, 1995; Akande and Erdtmann, 1998). A summary of our pertinent findings indicate that

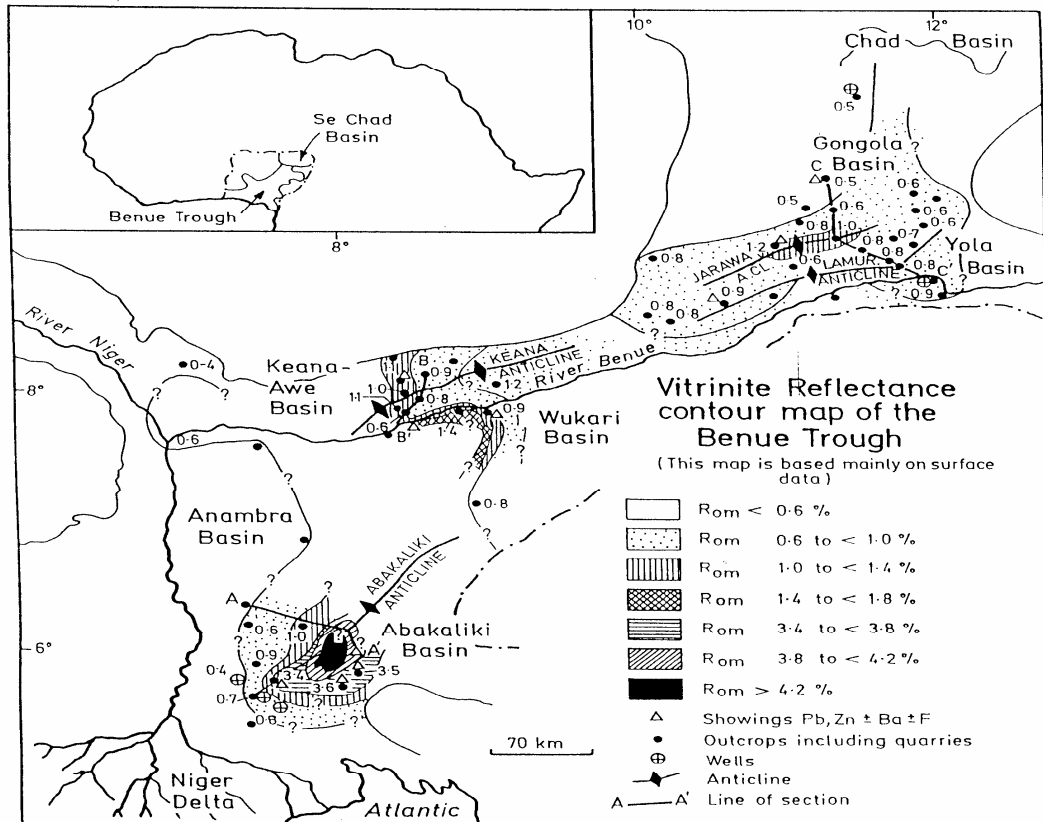


Fig. 10. Vitrinite reflectance contour map of the Benue Trough based mainly on outcrop data (from Akande, 2000).

the older Asu River Group sediments are overmature with respect to hydrocarbon generation whereas the range of maturity of the younger rocks (i.e. the Eze- Aku, Agwu and Nkporo Formation) and their source rock qualities suggest their capabilities to have generated hydrocarbons during burial (Akande & Erdtmann, 1998). Our reported findings if integrated in exploration strategies will aid the determinations of drilling depths to hydrocarbon reservoirs in the Anambra Basin (Akande & Erdtmann, 1998) (Fig.11).

(c) Petroleum potential of the Lokoja (Southern Bida ) Basin

This under-explored region has been one of the areas of our focus in recent years especially in respect of hydrocarbon resources. Although the area was classified to be of high risks in the initial exploration campaigns of the 70s and 80s (Whiteman, 1982) our recent studies of the Hydrocarbon source rock potentials and maturity of sediments in this region suggest a moderate to fair gaseous hydrocarbons potentials where the sediments are thickest (Akande & Ojo, 2002). Research on the reservoir rocks, migration pathways and trapping configurations of hydrocarbons in this basin are in progress (Ojo and Akande, 2003). (A summary of the level of maturation and kerogen types in the studied sedimentary basins is plotted in Figure 12. This confirms

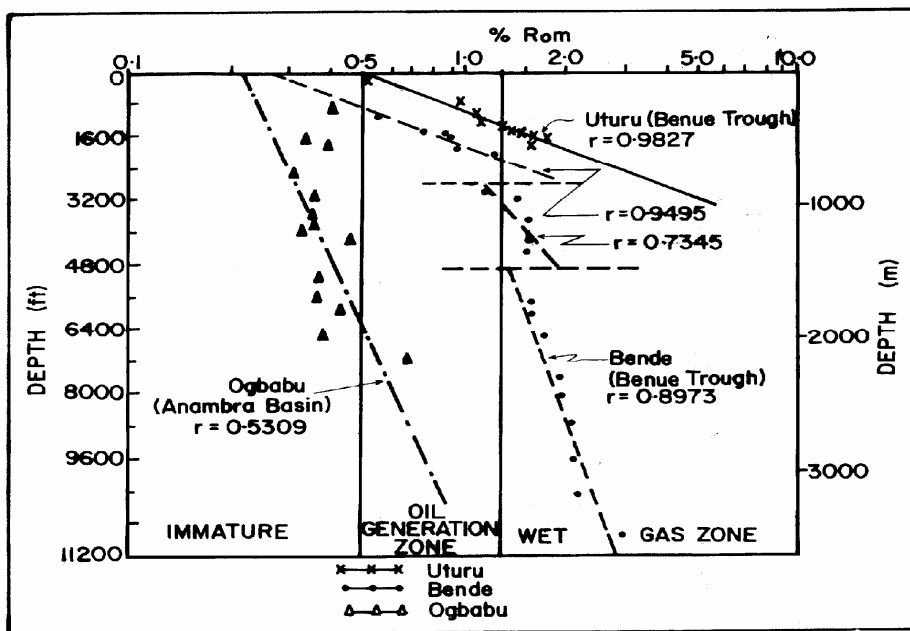


Fig. 11. Maturity patterns, oil window relations from vitrinite reflectance of exploration wells in the Benue Trough and Anambra Basin ( from Akande & Erdtmann, 1998).

the potential petroleum source rocks and prevalence of gas prone kerogen type III in the inland frontiers basins.

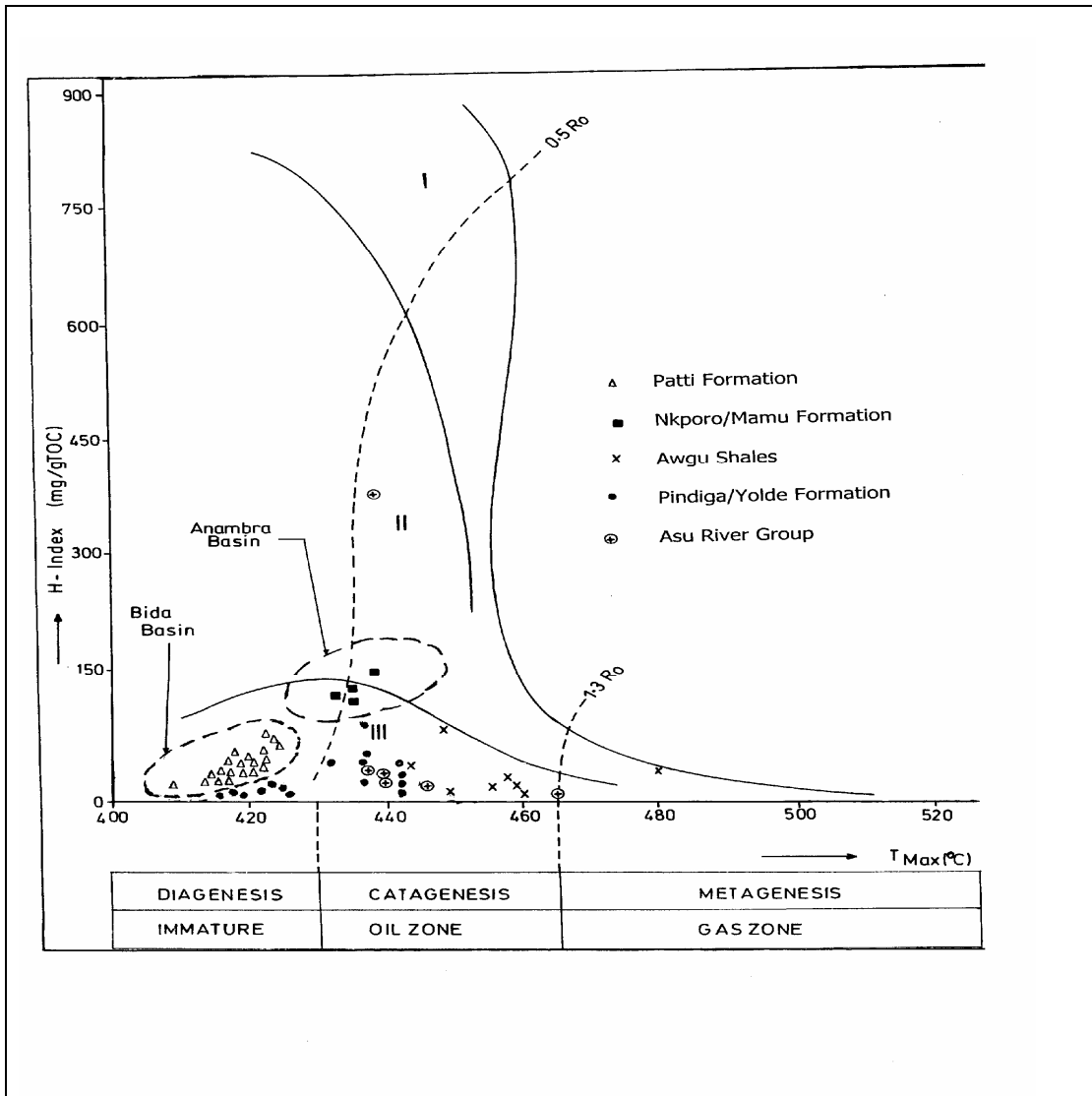


Fig 12. Maturity patterns and Kerogen types in petroleum source rocks of the Nigerian inland sedimentary basins (from Akande and Erdtmann, 2002).

#### 4.0 PROBLEMS OF MINERAL RESOURCES SUPPLY

At the beginning of this century, there were no major shortage of deposits hosting the over 40 minerals that we need. Some deposits are of such large sizes that they form economies in their own right: e.g. copper resources of the world are presently at all time high supply despite the enormously increased consumption. Such resource base should have made the base metal industry a competitive sector with other industries, however, the mining and investment community assessments indicate otherwise (Sheppard, 1997), (Macdonald, 2000).

Despite the volume of discovered reserves of base metal commodity, it is apparent that the new discoveries (which will add to the resource base) will be increasingly difficult to make in the next 25 years in view of the present downturn and decline in exploration activities. New additions to ores will be more difficult to come by and geologists will have to probe more and more intensively into the mysteries of ore-forming processes. There are indeed more attention paid to fossil fuel exploration in several frontier areas than the base metals.

#### 4.1 Mineral Resources Policy:

The sustainance of the mining industry is directly related to the type and nature of the mineral policy put in place by the state. Whereas such policy which include the regulatory and legislative guidelines should be amended from time to time, it should be so designed to create the enabling environment for the growth of the industry. Aspects of great importance in the policy frequently bear on the mining law, land policy, mineral taxation, trade policy, personnel, environmental guidelines etc.

It was reported that the period from 1905 – 1980 brought so many changes in the mineral policy of the USA that resulted into several adverse effects on the growth of the industry at which time the land policy placed restrictions on access. This led to very large areas withdrawn or closed effectively to mineral exploration and development. The greatest decline in exploration expenditure being in areas imposing the heaviest tax burdens. Funds for the industry are normally divided between capital, labour and government and the ultimate is to strike a balance between all of these. Any situation short of this may become less favourable for the industry leading to the shift in capital to non-mining ventures. The best option is to always encourage continuous state production to assist construction and industrialization of the world population. There is therefore no doubt that domestic demand will continue to attract phenomena increase. Responsible development, ethical governance and greater accountability will play greater roles in the management of mining ventures in order to increase operational performance and profitability.

The greatest challenge of the mining industry in Nigeria is to be able to develop its own technology for the exploration, development and production of minerals and fossil fuels. This should be the ultimate. A flexible policy should be in place at any period until this ultimate is attained. In the mineral sector, a policy is presently being implemented by the Ministry of Solid Minerals Development. The performance of this ministry could only be maximized if the ultimate goal of geological exploration, development, mining, production, auditing, legal etc. are structured into this ministry. The Geological Survey of Nigeria could then be an Agency in the Ministry with at least 5 technical departments committed to execute (i) Regional geology (ii) Mineral Exploration (iii) Applied geology (iv) Mines, Engineering parastatals and (v) Mines inspectorate as proposed to the Federal Government in the Solid Minerals Policy document Okigbo (1996).

While the policy in place in both the minerals and petroleum sectors may be adequate for now, the sustainance of both sectors depends on its vulnerability to both local and foreign investors. The state's priority however should be in future amendments of taxation, land policy, trade policy and environmental legislations depending on the available indigenous

technology and manpower. The establishments of the state parastatals e.g the Nigerian mining corporation, Nigerian coal corporation, Nigerian Uranium mining company, Bitumen project company, Nigerian iron ore mining company, Nigerian Steel Raw materials Agency which are parastatals for the solid mineral sector and the Nigeria National Petroleum Corporation (NNPC), Nigerian Petroleum Development Company (NPDC), Department of Petroleum Resources (DPR), Integrated Data Services Limited (IDSL), National Petroleum Investment Management Services (NAPIMS) in the Petroleum sector are steps in the right direction for the execution of the state mineral policy.

#### 4.2 Political and Social Environment:

In a recent inaugural lecture of a colleague Professor Kehinde Phillips (2002) titled “Rocks Enrich but Minerals Civilize and Vitalize”, the importance of the mining industry on the improvement of the quality of life by way of provision of the basic necessities for industrialization was stressed. This goal can only be achieved if this industry is given a place in the diverse political and social settings.

Whereas the development of mineral resources previously have a high priority in many parts of the world, it presently has a much lower priority in the national scheme; ranking below the preservation of wild life, wild rivers, natural parks and other scenic attractions of the wilderness. For instance, restrictions on mine fields became severe in the last century, in the USA with the passage of the Wilderness Act of 1964, despite the mineral industry requirements. This led to massive withdrawal of lands e.g. in Alaska which was previously a great frontier for mineral exploration. Similar socio-cultural problems and environmental protection problems too led to several legislations. The mining industry was affected to such an extent that a longer gestation period between discovery and production became the order of the day. Some of the legislations led to many identified ores that could not be brought into production even after spending exploration and development dollars on Environmental Impact Assessments. A copper deposit at Ladysmith in northern Wisconsin was discovered in 1968. Based on the environmental sensitivity, there were protracted hearings on the issue of development and mining until 1978 when mining permit was refused by the State (Cameron, 1981).

Obviously, the mineral industry deserves a better policy for adequate mineral supplies within a reasonable controllable environmental damage.

Since the oil and gas crisis of the 70s this industry has also been a prime target for more legislations (Meadows, 1972). The negative impact of this is reflected in the exclusion of large land areas of known potential from oil mining industry in view of the track record on the environment attributed to the industry. It is important for the public to know that they need the minerals and the non-renewable energy resources. With the rarity of these commodities, geologists will face the task of looking for them in an enabling environment which should be provided by government.

The greatest challenge for the mineral and energy industry in the 21<sup>st</sup> century will be to improve profit, for the minerals industry to regain its status as creator of new wealth. A

major change of emphasis in operational controls is therefore required; greater geological understanding is needed especially to grade and recovery in a politically stable environment.

### 4.3 Resource Personnel

Discussing problems of mineral resources supply will not be complete without touching on the personnel needs. One of the key aspects of improving the resource base involve the active participation of the resource persons and professionals in the field. In the field of exploration, geoscientists and technical staff are needed. Whereas, adequate provisions are made for personnels needed for the minerals, oil and gas industry, in the developed world, there is still a low average of highly qualified geoscientists and technicians to perform the task in the developing world. For instance, the India Geological Survey has more than 3000 geoscientists and over 15,000 technical staff, whereas in Nigeria, there are only about 200 geoscientists and a quarter of this number as technicians in our own Geological Survey. Considering our land and sea space, we need at least 10 times this number if we have to adequately evaluate our resource base in this space and provide key information for the mining industry. The diverse minerals and fossil fuels potential in Nigeria obviously demand participation of a large number of geoscientists having a minimum of MSc Degrees in the field of geosciences including Applied geophysics. Professionals with this minimum level of qualifications are much easier to be trained and retrained for adequate management of their portfolios.

## CONCLUSIONS AND RECOMMENDATIONS

Mr. Vice chancellor, Ladies and Gentlemen, I wish to state that minerals and fossil fuels form economies by their own rights and are vital sectors of the world economic trade. They do enrich, sustain and improve the quality of life, where they occur in abundance and indeed several economies including Nigeria depend largely on mineral wealth without which the nations would be nothing than barren lands.

Minerals and fossil fuels are being discovered by geologists who explore and develop them before production by various working teams including geoscientists. Therefore geoscientists should be encouraged to find new deposits needed to sustain the enormous world population of almost 7 billion. They should be encouraged to improve the modern prospecting and exploration techniques. The mining industries need the raw materials for its growth, development and provisions of technological requirements. The adventures of exploration and success in the upstream sectors of the mining industries translate into products worth enormous amount of dollars in the downstream sectors, frequently enrich the populace and sustain their quality of life.

I have taken you through the history of prospecting and exploration of minerals and fossil fuels and the adventures involved including the techniques of modern prospecting and exploration problems of non- renewable mineral resources supply and my contributions to the science of their exploration.

The facts enumerated in the early part of this lecture showed that geological raw materials are depletable, non-renewable resources, therefore exploration for sustainability

and increase in resources must be a continuous process. The strong cautionary notes have to be sent to the developing nations in particular where tendency of overproduction for short-term gains are frequent. The present knowledge indicates that the “easier to find ores are already depleted” and new finds or discoveries call for intensive explorations to increase the resource base. Minerals and hydrocarbon deposits have approximate life indices. For example the huge resources of oil (ca. 32 billion barrels in reserves) and gas (> 160 trillion cubic feet) today in place in our own Niger- delta will be depleted in 30 years ( at least for the oil) and about 90 years for the gas if these resources are not increased by intensive exploration. Today, estimates of about 20 billion barrels of oil have been pumped out of our Niger delta since the commencement of production in 1956 .This is another reminder for government to diversify the economic base from oil and gas into other sectors of mineral resources especially the metallic and non-metallic industrial minerals. To do this, geological exploration is a must, should be part of the government priority and adequate policy should be in place. It is therefore pertinent that a constant evaluation, re-evaluation of the resources be made on regular bases. This calls for a constant review of the available technology being applied for the exploration, development and production of each commodity. It is pertinent that adequate education, personnel training is needed for the systematic compilation and interpretation of information on energy and mineral resources.

Mr. Vice Chancellor in view of the need for a massive exploration, development and production of mineral and fossil fuels resource base in Nigeria I have the following recommendations for the government.

- 1) In as much as minerals and fossil fuels are indeed the economic base of nations, we have no choice than to continue to find new deposit types. Geologists have to discover them; I recommend that detailed update on mineral resources inventory should be carried out in each state of the federation and reserves of all commodities, grades and future needs of each commodity be updated annually. This adventure is inevitable to sustain our wealth.
- 2) Government should continue to make periodic amendments to existing fiscal policies, incentives and contractual guidelines in order to create favourable conditions for the wide range of investors in the mineral sector as commonly practised in the oil and gas sector. Currently the Nigerian government guarantees an efficient oil producer a profit margin of at least \$2.00 per barrel of oil produced even when the prices fall as low as \$12.50 per barrel. Such incentives will no doubt encourage exploration and exploitation leading to increase in revenue. I recommend even a better incentive for the harsher and the “more difficult to produce” deeper offshore fields and adequate tax holidays too, for investors in the solid mineral sector.
- 3) Export of wide array of non-metallic industrial minerals should be encouraged especially in the processed form. This step should complement the development of catalytic small scale model factories for the utilization of industrial minerals like clay, talc, marble, phosphate, soda-ash and gemstones.

- 4) The geologists believe that Nigeria is endowed with significant quantities of minerals and fossil fuels deposits as discussed in the earlier sections. It is time to strategically harness the resources, identify those to be stock piled and prevent overproduction for short time gains. There is need to classify and re-group our mineral resources for strategic purposes in tune with the world economy which must be constantly reviewed.
  
- 5) In the field of research, I recommend that government should mandate its relevant parastatals e.g. the Nigerian National Petroleum Corporation {N.N.P.C.}, The Nigerian Mining Corporation {N.M.C.}, Raw Material Research Development Agency {R.M.R.D.C.}, the Ministry of Science and Technology to sponsor research directed to minerals and fossil fuels deposits in our universities that are offering clear geosciences programmes under specific outlined budget for this purpose. Such research should focus on describing specific deposits, formulation of the models and possible technology, for their exploration, development and production in our own environment. Such policy has proven to be self sustaining in countries like U.S.A., Canada and Australia where local indigenous exploration models and technology exist and small-scale mining and production of mineral commodities that would otherwise have been non-economic are in operation.

Mr. Vice Chancellor, ladies and gentlemen, we need to continue to discover new deposits of minerals and fossil fuels to sustain our industries and improve the quality of life; the modest discoveries by early prospectors had developed into the challenges of modern mineral exploration and both the exploration successes and failures can be interpreted through geological processes. These are adventures that must continue as long as “homo-sapiens“ remain on this planet..

## **6.0 ACKNOWLEDGEMENTS**

In an occasion like this, it is customary to give honor to whom honour is due. My foremost gratitude goes to God Almighty for sparing my life to see this day, for being my strength, my rock and my guide throughout.

My sincere thanks go to my parents Deacon Joseph Oluwole Akande and my mother Deaconess Felicia Folorunso Akande who recognized and appreciated the goodness and importance of education and so considered it as their obligation to send me to school and to inculcate in me good moral education and perseverance. Indeed, I cannot forget to remember my father’s words which remind me always that “Quality Education is a must in a man’s life”. I thank you very much and to God Almighty for making it possible for you to see this day. My unalloyed gratitude also goes to my Auntie Mrs. Titilayo Akisanmi and uncles Engineer Chief Jibola Aderoju and Chief Idowu (Baba Wale) for all your encouragements and support throughout my time in school and even till this day. I thank the extended Akande family representatives from Abeokuta, Lagos, Lanlate and Ibadan and my in-laws here present led by Papa Michael Kehinde Sotunde from Ibadan.

I cannot but acknowledge my teachers at the great High School on Adeke Heights “ The Baptist Boys High School now Baptist High School Iwo” where the sound foundation of

Science was laid and the pioneer motivation for me to be a geologist was given not by coincidence but by the divine control of God Almighty. My sincere thanks also go to all lecturers at the Department of geology, University of Ibadan where the ABC of geology was taught especially to my mentor, teacher and father Professor M.O. Oyawoye who was used by God, to encourage me from the first day as an undergraduate to this level. Mention must be made to other professors at U.I at that time – Professors K.C Burke, M.A. Fayose, M.A. Rahaman {now of O.A.U. Ife} and Dr Adeleye who were always there as at when needed.

My M.Sc. degree in geology would not be possible without the supervision of now Emeritus Professor Robert W. Hodder, of the University of Western Ontario, London Canada, Professor R.W. Hutchinson now of the Colorado School of Mines. The motivation and enthusiasm of the professors at Western led me into doing Ph.D at Dalhousie University, Halifax supervised by Professor Marcos Zentili – a teacher, scientist and excellent motivator. I learnt quite a lot from Marcos and each time I express my appreciation to him he replies “ Sam, you don’t owe me anything , just pass unto others whatever you have learnt and gained from me” Professor Zentili is a close friend to my family and he is always there for me in Canada. He was happy to receive me once again in Canada some few months ago when he invited me to my old department to give a talk to the department on my adventures so far in exploration.

I wish to place on record my appreciation of various other colleagues abroad with whom I have collaborated to achieve some of the contributions highlighted in this talk. Notable among these are the members of the German group of Technical University Berlin, Germany, led by Professor Dr. Bernie Erdtman; the University of Gottingen Germany, led by Professor Dr. Elfrun Horn, The Hungarian Geological Survey, Budapest led by Professor Dr. Istvan Viczian and those in Atilla Jozsef University, Szeged led by Professor Dr. Magdona Hetenyi. I will always remain grateful for your assistance, cooperation and encouragement to me and my postgraduate students who have benefited from your continuing support and assistance too by visiting your laboratories to complete their Ph.D laboratory analysis.

My gratitude goes to my colleagues and all staff members of the Department of Geology and Mineral Sciences of this University for all the cooperation I have received from you singly and severally at all times to make a unique and united department free of divisions. Your support, cooperation and uprightness have been so wonderful making that Department an indivisible one in this University. I frequently remember our modest beginning and thank God for leading us thus far. May God continue to bless UNILORIN Geology Department –Amen.

I wish to thank my two children Gbemisola and Funmilayo for their understanding when I have to stay away for days in the field, months abroad and long hours in the laboratory. I remember a particular occasion when Funmilayo was just a little girl of only over 1 year old when I had to go on a study leave of 6 months in Canada, I came back 6 months later only to see her looking carefully at me without saying a word unlike before my departure when she was always happy to see me arrive from school to sing a song for her. I fully appreciate your continuing forbearance and thank God for sparing your life. Indeed both of them “word process” a major portion of this lecture on the family desktop. Finally let me express my appreciation to my wife Mrs. Rhoda Omobola Akande for her invaluable contributions to my great success. She stood loyally by me and with me from my humble

beginning, through the rough times, through the numerous long absence on field trips, conferences, workshops both at home and abroad in my exploration adventures. I thank you for your perseverance. Mr. Vice Chancellor, distinguished guests, ladies and gentlemen, I thank you all for the audience - good night and God bless.

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