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TINY ANCIENT ORGANISMS IN ROCKS: THEIR ROLE IN THE NIGERIAN ECONOMY

By

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Professor of Geology

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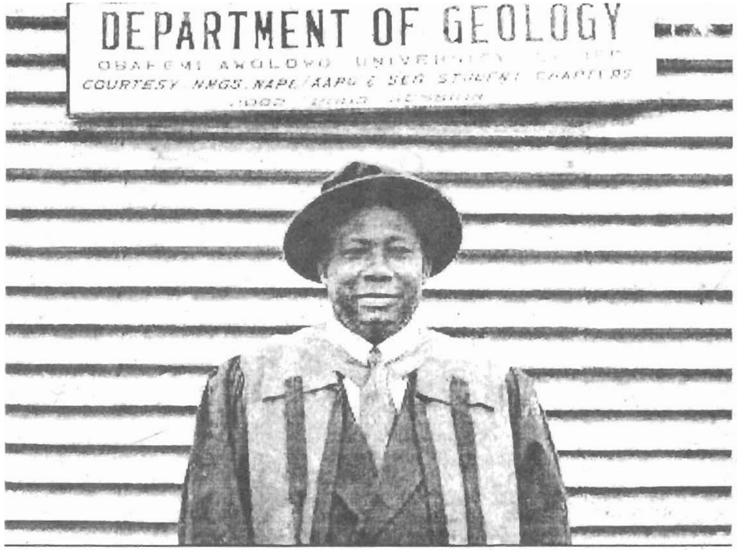

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INTRODUCTION

Very tiny plants and animals and / or their parts occur preserved in rocks that range in age from more than three billion years old to the present day. These remains/remnants of ancient organisms contained in rocks have been known for many centuries (Berggren, 1978). When they were first noticed, however, their observers apparently did not know what they were and how they came into existence. Consequently, this early scenario was rich in fanciful speculation and some very funny interpretations were given to them.

The earliest written records of such ancient organisms (contained in rocks) date from classical times, precisely between the 5th Century BC and 1st Century AD when Greek and Roman philosophers inferred that the sea shells found on mountain slopes were once living forms. These records (**Figure 1**) are those of

- Herodotus (*ca* 484 to 425 BC), an ancient Greek Historian called the Father of History,
- Pythagoras of Samos (*ca* 560 to 480 BC), the notable Greek philosopher, mathematician, astronomer, musician and religious leader,
- Aristotle (384 to 322 BC), who was Plato's student and one of the finest biologists / natural historians ever to live,
- Strabo (63 to 03 BC), another Greek historian, geographer, and philosopher and
- Pliny the Elder or Caius Plinius Secundus (23 to 79 AD), a Roman officer and encyclopaedist, and also the author of the ***Natural History***.

My search through the *Holy Bible* and the *Holy Qur'an* has not yielded an account of such ancient organisms preserved in rocks. ***(Perhaps I was not diligent enough in the search. I therefore stand to be corrected.)***

The first **tiny** ancient organisms to be mentioned in recorded history (*cf.* Boersma, 1978, Haq and Boersma (1978), Brasier(1980),Bignot(1985)) were the relatively large single-celled protozoans called ***Nummulites***. The shells (or skeletons) of ***Nummulites*** (**Figures 2a – d**) are coin-shaped and calcareous in composition (i.e. made of calcium carbonate) and have very complex interiors (**Figures 2e – f**). They accumulated in such enormous numbers that they formed huge limestone beds. They were thus **great** rock builders.

Herodotus **(about 484 to 425 BC)**

Pythagoras **(about 560 to 480 BC)**

Aristotle **(384 to 322 BC)**

Strabo (63 to 03 BC)

Pliny the Elder **(23 to 79 AD)** ***Chu Hsi***

Figure 1: The Ancient Greek and Roman Philosophers (excluding *Chu Hsi)* who Contributed to the Study of Ancient Organisms Preserved in Rocks.

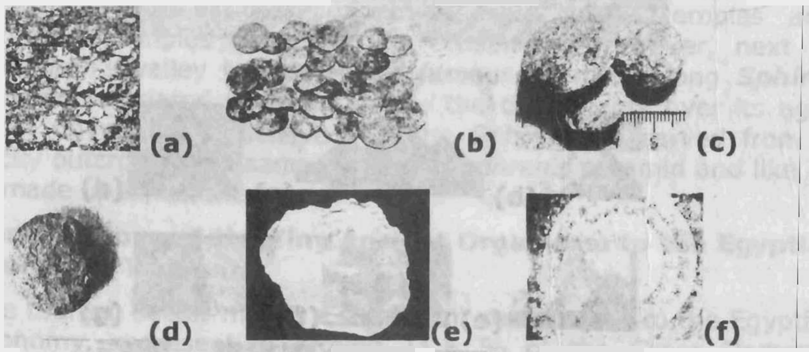


Figure 2: Skeletons / shells of *Nummulites*, the Ancient Tiny Organism Rock Builders

To appreciate how great they were as rock builders, one must consider certain structures that were built from rocks that are made of ***Nummulites*** shells: the Great Pyramid of Giza (in Egypt) and the nearby pyramids. In fact Herodotus, the fifth century B.C. Greek historian who was the first to record them thought that the disc-shaped nummulitids were lentils (fed to the slaves who built the pyramids) that had accidentally spilled and had turned to stone.

These Egyptian Pyramids (**Figures 3a – j**) are colossal structures used by the ancient world for religious and burial purposes or as monuments to what were considered as great Pharaohs. The largest and most remarkable of the pyramids occur in several groups on the west side of the Nile River extending for a distance of about 40 kilometres reaching as far as Cairo (Egypt's capital city). They date from 3000 to 2300 BC.
They were built from hard limestone and large blocks of limestone, especially on the outside surface. The rocks are about 45 million years old, having been formed in the Geologic age called the **Eocene.**

Great skill was needed to quarry these large blocks, transport them and then place them in position. Kings built the pyramids as their tombs or memorials and it is thought that they were started at the beginning of each reign and that the height corresponded with the length of each reign.

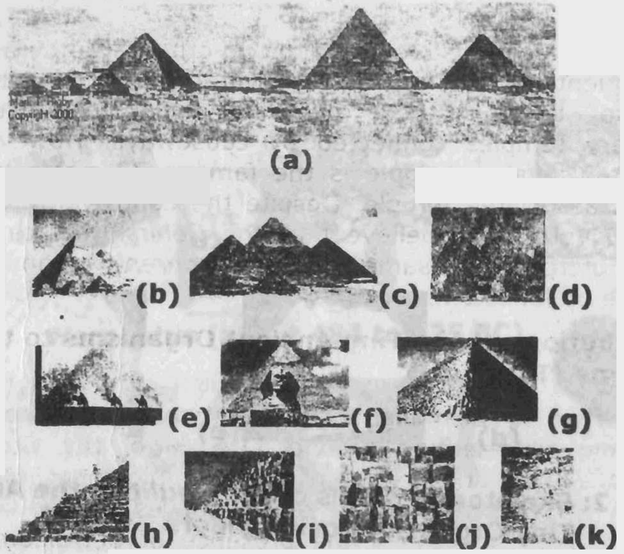
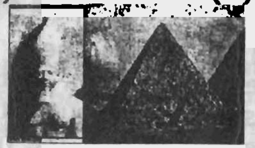


Figure 3: Various Views of the Pyramids at Giza (a – g) and their Building Blocks (k – j). The sphinx is shown in (f).

The largest Egyptian pyramid ever built was the ***Great Pyramid*** at Giza, located southwest of modern Cairo. Built for King ***Khufu*** (otherwise known as **Cheops**), this pyramid was completed around 2550 BC. It is estimated to contain about 2,300,000 blocks of stone with an average weight of 2.5 tonnes each and some weighing up to 15 tonnes. Its sides measure 230 metres in length and the structure would have towered about 146.6 metres high, but it is now a little shorter owing to the removal of the outer casing to construct many of Cairo's buildings during the middle Ages.

(a) ***Khurfu*** (Cheops) (b) ***Chephren*** (Khafre)



(c) ***Menkaure***

Figure 4: Three of the Pharaohs Who Built the Pyramids at Giza

The Giza Plateau also is home to two other large pyramids for the subsequent kings, ***Chephren*** and ***Menkaure***. As with the Great Pyramid, both of these pyramids have valley temples and mortuary temples connected by causeways. However, next to *Chephren's* valley temple is the famous 73-metre long ***Sphinx*** and its associated temple. Despite the controversy over its age, most Egyptologists believe that the *Sphinx* was carved from a rocky outcrop at the same time as *Chephren's* pyramid and like it, is made up limestone.

Contributions of the Tiny Ancient Organisms to the Egyptian economy (Tourism):

The tourism sector makes a significant contribution to the Egyptian economy, representing around 11.6 % of the Gross Domestic Product (GDP) and 15 % of total employment (James, 1982; Lawton and Ogilvie-Herald, 2000; Reeves, 2000; Arnold, 2003, Hawass, 2003;). Despite the presence of petroleum deposits in Egypt, Anorld, 2003, **tourism** is the largest foreign exchange earner in the country. It attracted 2.98 million visitors and generated an amount estimated as between US$ 3.8 billion and US$ 4.3 billion in 2001. According to official figures released in January 2005, during the first 11 months of 2004, some eight million tourists visited Egypt, injecting $6.5 billion into the country's economy. A considerable proportion of these tourists visit the Great Pyramid and other pyramids of Giza every year. More than four thousand and five hundred years old, the Great Pyramid is considered one of the seven wonders (and the only surviving one) of the ancient world.

These pyramids could be built and are here today to contribute to the Egyptian economy, thanks to the millions of ***Nummulites*** individuals who, on death, left their shells / skeletons behind to make the limestone which eventually provided the huge building blocks for the pyramids.

Mr. Vice-Chancellor Sir, just like in Egypt, these tiny ancient organisms preserved in rocks have, as the title of this lecture implies, contributed and continue to contribute immensely to Nigeria's economy. Indeed, they have, over the years contributed enormously to the economy of all the petroleum-producing countries the world over. These and other such ancient organisms whose remains are preserved in rocks are called **microfossils.** Consequently, an alternative to the title of today's lecture could be

The Role of Microfossils in the Nigerian Economy.

But then, what are Microfossils?

Microfossils can be simply defined as tiny **fossils** that are so small (usually less than one millimeter long) that they can only be adequately studied with the aid of a microscope. A **fossil** is any remains (skeleton, shells, teeth, etc.), trace, or imprint of a plant or animal that has been preserved, by natural processes, in the rocks that occur on the Earth's outer layer, since some past geologic time (Gary *et al.*, 1972). The study of fossils is called **paleontology** and that of microfossils is known as **micropaleontology.** The student of micropaleontology is called a **micropaleontologist**.

Leonardo da Vinci (1452 - 1519), the great Italian painter, sculptor, architect, musician, engineer and scientist (**Figure 5**), whom I consider one of the greatest geniuses of all time, is credited in the Western World as the first person to have correctly interpreted the organic nature of fossils i.e. the fact that they were remnants of ancient organisms. In addition, by direct observation, he also realized the value of the information that can be gleaned from them.

However, Leonardo da Vinci had probably been anticipated by about three centuries by the Chinese scholar, **Chu Hsi** (1130 to 1200 A. D.), who in a 1227 publication apparently perceived their true nature (Boersma, 1978).

Figure 5: Leonardo da Vinci (1452 to 1519) and two of his most famous paintings: *Mona Lisa* and *The Last Supper*

As a discipline, **micropaleontology** cuts across many classificatory lines and includes within its domain the study of large numbers of taxonomically unrelated groups united solely by the fact that they must be examined with a microscope (Berggren, 1978). Simultaneously, within certain taxonomically homogeneous groups, the size of some forms is such that they scarcely need be examined with the help of a microscope. They are thus more properly grouped under **macropaleontology,** the study of large fossils. Consequently, micropaleontology lacks a definite coherent homogeneity.

Most microfossils are **protists** (unicellular plants and animals), but others are multicellular or microscopic parts of macroscopic forms. Their grouping into one discipline thus remains essentially practical and utilitarian (Berggren, *op. cit.*).

Traditionally, and as used in this lecture, the term **micropaleontology *sensu lato*** included the study of all types of microfossils. However, modern workers, from a practical perspective consider that three disciplines are involved: **micropaleontology *sensu sricto***, **nannopaleontology** and **palynology**. The separate disciplines have arisen due to differences in the size and chemical composition of particular microfossils, which impose the need for specific preparatory and analytical procedures (Bignot, 1985; Brasier, 1980; Glaessner, 1963; Jones, 1956; Jones, 1996, Boardman *et al*. 1987).

Micropaleontology *sensu sricto* involves the study of **foraminifera, ostracodes** and **calpionellids,** which mainly have calcareous skeletons; **diatoms** and **radiolaria,** which are composed of silica; and **conodonts**, which are phosphatic. Routine identifications employ incident light microscopy. In some cases, thin-section analysis is required, as in the case of the study of larger **foraminifera** and **calpionellids**.

Nannopaleontology covers the study of **nannofossils**, which are the smallest of the microfossil groups routinely examined. This group includes **coccoliths** and **nannoliths**, and also **calpionellids**. Nannofossils are calcareous and examined in transmitted light. They need polarization techniques for positive identifications to be made.

Palynology was once limited to the study of **spores** and **pollen** (Brasier, 1980). However, in the last fifty years, the field has been extended to encompass other organic-walled microfossils, collectively termed **palynomorphs**. The groups studied include **dinoflagellate cysts (dinocysts), acritarchs**, marine **prasinophyceaen algae** and various **freshwater algae, chitinozoa**, as well as spores and pollen. **Palynomorphs** are examined in transmitted light. In addition to palynomorphs, palynological preparations often yield a variety of other fossil remains (foraminiferal test-linings, arthropod fragments and fungal material) and organic debris (amorphous organic matter and a range of **structured phytoclasts**). These components, together with the specific palynomorphs present, are important in **palynofacies analysis**.

The students of nannopaleontology and palynology are known as **nannopaleontologists** and **palynologists** respectively.

Advantages of Microfossils over Macrofossils:

Microfossils have an enormous advantage over macrofossils in various fields of Geology. Their practical value is enhanced by their minute size, abundant occurrence, and wide geographic distribution in sediments of all ages and in almost all marine environments (*cf.* Berggren, 1978). Their small size and numerical abundance enable relatively small sediment samples to yield enough data for the application of more rigorous quantitative analytical methods. Furthermore, most planktic and many benthic microfossils have wide geographic distributions that make them indispensable for regional correlations and comparisons, and paleoceanographic reconstructions. Finally, microfossils occur in sediments of Precambrian (i.e. older than 600 million years) to Recent ages and in every part of the **Geologic Column (Figure 6)**. One or more microfossil groups can thus always be found useful for **biostratigraphic** and **paleoecologic** interpretations.

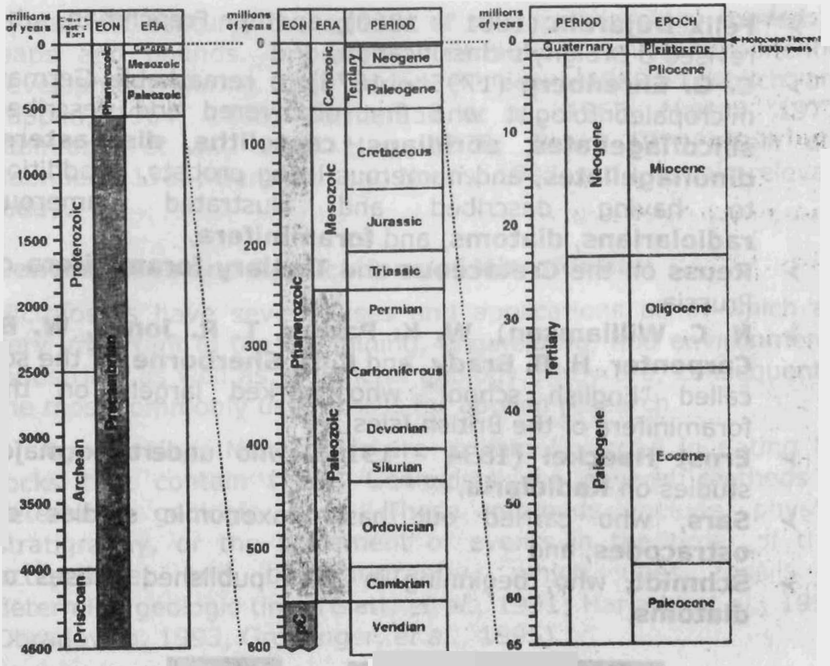


Figure 6: The Geologic Time Scale

Milestones in the Study of Microfossils (Figure 7):

The earliest mention of microfossils dates back to the 5th century B. C. when Herodotus recorded the great rock builders, ***Nummulites***. However, the systematic study of microfossils had to await the discovery of the microscope by **Antonie van Leeuwenhoek** in **1660**. This is apparently an apt date to indicate the birth of **systematic micropaleontology**.

The **binomial nomenclature**, which is the basis of modern biological nomenclature, was first applied to fifteen foraminiferal species in the 10th edition of **Linné**'s ***Systema Naturae*** published in **1758**. From about **1826** to **1884**, eminent workers undertook detailed, mainly descriptive, studies on many of the major microfossil groups. These studies / workers include:

- **Alcide d'Orbigny** (1802 – 1875), a Frenchman who undertook a comprehensive classification of foraminifera and studied the **biostratigraphy** of the **Paratethyan Tertiary**,

- **Felix Dujardin** (1801 – 1860), another Frenchman, who revised d'Orbigny's classification,
- **C. G. Ehrenberg** (1795 – 1876), a remarkable German micropaleontologist who first discovered and described **silicoflagellates**, **ebridians**, **coccoliths**, **discoasters**, **dinoflagellates**, and numerous living protists, in addition to having described and illustrated numerous **radiolarians**, **diatoms**, and **foraminifera**,
- **Reuss** on the **Cretaceous** and **Tertiary foraminifera** of Prussia,
- **N. C. Williamson**), **W. K. Parker**, **T. R. Jones**, **W. B. Carpenter**, **H. B. Brady**, and **C. D. Sherborne**, of the so-called "English school" who worked largely on the foraminifera of the British Isles,
- **Ernst Haeckel** (1834 - 1919), who undertook major studies on **Radiolaria**,
- **Sars**, who carried out basic taxonomic studies on **ostracodes**, and
- **Schmidt**, who, beginning in 1875 published atlases on **diatoms**.

Leuweenhoek **Haeckel** **Linné**

d'Orbigny **Ehrenberg** ***H.M.S. Challenger***

Figure 7: Some Contributors to the Development of Micropaleontology as a Discipline

The single largest motivation to descriptive micropaleontologic studies in the latter half of the 19th century was the voyage of ***H.M.S. Challenger*** from 1873 to 1876. **H. B. Brady** published a monumental monograph of the **foraminifera** dredged by the ***Challenger*** during its voyage around the world (Brady, 1884). This work remains, to this day, the fundamental reference in the study of **Neogene** and living foraminiferal faunas.

In the last century, the science of micropaleontology moved by leaps and bounds. Important contributions to its exponential development during that period (Phleger, 1960; Loeblich and Tappan, 1964, 1988; Germeraad *et al.*, 1968; Martini, 1971; Stainforth *et al.*, 1975 Haq, 1978; Blow, 1979; Bolli and Saunders, 1986; Berggren and Norris, 1997; etc.) remain relevant today.

General Uses and Applications of Microfossils:

Microfossils have several uses and applications all of which are very important in the oil, mining, engineering, and environmental industries, as well as in general geology. They are, consequently, the most commonly used fossils for applied research.

(i) ***Age-Dating:*** Microfossils are extremely useful in dating the rocks that contain them. Geologists use several methods to determine geologic time. These methods include physical stratigraphy, or the placement of events in the order of their occurrence, and biostratigraphy, which uses fossils to determine geologic time (Blatt, *et al.*, 1991; Harland *et al.*, 1990; Obradovich, 1993, Grotzinger, *et al.*, 1995).

The use of fossils for dating is founded on the fact that organisms that produced them lived at particular times in the past, evolved with time, and that evolution is irreversible. The process of determining geologic time includes several steps. Geologists first determine the relative age of rocks—which rocks are older and which are younger. Next, they construct a geologic time scale (**Figure 6**). Finally, they determine the specific numerical ages of rocks by various dating methods and assign numbers to the time scale.

Geologists create a relative time scale using rock sequences and the fossils contained within these sequences. The scale they create is based on the **Law of Superposition**, which states that in a regular series of sedimentary rock strata, or layers, the oldest strata will be at the bottom, and the younger strata will be on top.

An alternative used by geologists **is radiometric dating**, which involves the use of the rate of decay of certain radioactive elements in minerals to assign numerical ages to the rocks (e.g., Holmes, A., 1937).

(ii) ***Biostratigraphic Correlation:*** Another method in use is **correlation**, which allows geologists to determine whether rocks in different geographic locations are the same age. Using correlation to determine which rocks are of equal age is important for reconstructing 'snapshots' in geologic history. Correlation may use the physical characteristics of rocks or fossils to determine equivalent age. For example, the limestone at the top of one side of a canyon can be correlated to its opposite side. Also, ash from a volcanic eruption can be correlated over long distances and wide areas. However, fossils (particularly microfossils) are the most useful tools for correlation. Since the work of Smith and Cuvier, biostratigraphers have noted that "like fossils are of like age." This is the principle of fossil correlation.

(iii) ***Paleoenvironmental Reconstruction:*** This use is based on the fact that organisms live in particular environments and specific niches within the environments / habitats and presumably did in the ancient past. Consequently, depositional environments of relatively young sedimentary rocks are interpreted by comparing the fossil assemblage in them with the habitats of the assemblages' living relatives. For older sedimentary rocks, more sophisticated methods are used (e.g., Emiliani, 1954; Grimsdale and van Morkhoven, 1955).

(iv) ***Other uses in Geology*** include ***paleoecology, paleoclimatology*** and ***plaleoceanography*** (MIRACLE, 2005) as well as the search for, and exploitation of, petroleum (Armentrout, 1991; Galloway, 1989; Haq *et al.*, 1987; Lipps, 1981, 1992).

Use of Microfossils in Petroleum Exploration:

One of the most important applications of micropaleontology today is in oil exploration. Due to their small size, microfossils have become an important stratigraphic tool in the hydrocarbon exploration and development industry. This is because rock samples are often limited to small fragments (cuttings) brought up from the well bottom by circulating drilling mud (Jones and Simmons, 1999).

Petroleum is derived from decayed phytoplankton, microorganisms that live in the sea. When phytoplankton die, they sink to the sea floor where they begin to accumulate. The deposited phytoplankton is covered by other sediments and pushed deeper into the crust of the Earth, where it is subjected to higher pressures and temperatures. Only then will phytoplankton change structure and become **kerogen**, heavy oil and finally light oil, which is used for petroleum. This complex process means that not all formerly marine environments will yield petroleum (Fleiser and Lane, 1999).

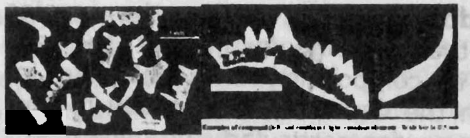
The remains of phytoplankton, microfossils, in petroleum-bearing rocks undergo changes in colour because of heat. Micropaleontologists study their alteration in colour to define possible areas for oil exploration. When these fossilized microorganisms are pale or orange the sediment is immature, when they are brown the rocks are mature, indicating oil, and when the fossils are black, they indicate gas.

Types of Microfossils:

The **nine major** microfossil groups (**Figures 8** to **18**) that are routinely studied by micropaleontologists are (01) **calpionellids,** (02) **conodonts**, (03) **diatoms**, (04) **nannofossils**, (05) **ostracodes**, (06) **radiolarians**, (07) **silicoflagellates** (08) **foraminifera**, and (9) **palynomorphs** (Brasier, 1980; Fleisher and Lane, 1999).

(01.) **Calpionellids** (**Figure 8a**) are small calcareous, cup-shaped microfossils. They are best known from Mesozoic pelagic limestones of the Tethyan realm.

(a) Calpionellid



(b) Conodont and Conodont elements

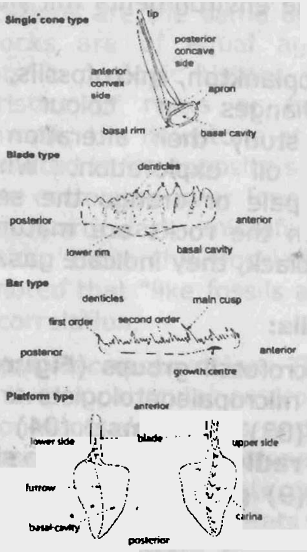
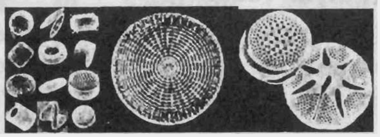


Diagram showing morphological terminology redrawn from Muller 1978

(b) Conodonts and Conodont elements (continued)



(c) Diatoms

Figure 8: Major Microfossil Groups – (a) Calpionellids, (b) Conodonts and (c) Diatoms

(02.) **Conodonts** (**Figure 8b**) are the remains of some unknown organisms that became extinct at the end of the Triassic. Phosphatic in composition and tooth-like in appearance, they ranged from the Cambrian (about 600 million years ago) to the Triassic. They were particularly prominent in the Ordovician and Late Devonian. Conodont elements exhibit just a few basic components - cones, bars/blades and platforms.

(03.) **Diatoms** (**Figure 8c**) are unique forms of algae that photosynthesize and grow a silica shell called a **frustule** that is preserved in underwater sediments after they die. Diatoms live anywhere there is water, including lakes, streams, estuaries, oceans, and puddles. They provide a significant amount of the world's oxygen supply (some say 35%). Over a hundred thousand Diatom species have been identified to date (Blome *et al*, 1995). They form a rock known as diatomite or diatomaceous earth, which is sometimes used in pest control.

(04.) **Nannofossils** (**Figure 9**) are calcareous in composition and include the **coccoliths** and **coccospheres** of haptophyte algae and the associated **nannoliths**, which are of unknown origin. The organisms, which create the coccospheres, are called coccolithophores. They are phytoplankton autotrophs (that contain chloroplasts and photosynthesise). Their calcareous skeletons are found in marine deposits often in vast numbers, sometimes making up the major component of a particular rock, such as the chalk of England.

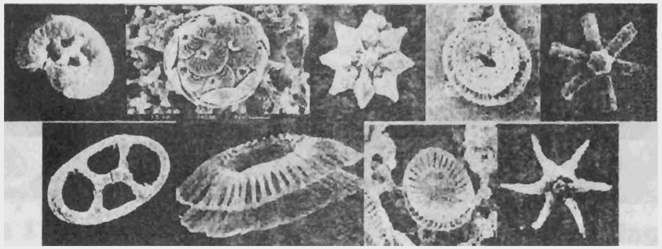


Figure 9: Calcareous Nannofossils

(05.) **Ostracodes** (**Figure 10**) are by far the most complex organisms studied within the field of micropalaeontology. They are Metazoans and belong to the Phylum **Arthropoda** (as do trilobites and insects), and Class **Crustacea** (as lobsters, shrimps, crayfish and crabs). An important distinguishing feature that **ostracodes** share with other arthropods is the bilateral symmetry of their body form. They are aquatic crustaceans whose paired soft body parts are completely enclosed in a dorsally hinged fully calcified shell (or **carapace**) consisting of two valves. Many are less than 1.0 mm long, so that even their gross anatomy requires microscopic study, and many structural details could not be investigated until the advent of the scanning electron microscope. It is the calcareous carapace that is commonly preserved in the fossil record (Maddocks, 1992; Benson, et al., 1961; Hartmann, 1966, 1967, 1968, 1975, 1989; van Morkhoven, 1982, 1983; Pokorny, 1978).

The six recognized orders are ubiquitous and diverse, with over 50,000 named genera and species and more awaiting study (Kempf, 1988). The calcareous carapaces are abundant microfossils in sediments of most marine and terrestrial environments, and there is a rich fossil record extending back to the Cambrian.

They are found today in almost all aquatic environments including hot springs, caves, within the water table, semi-terrestrial environments, in both fresh and marine waters, within the water column as well as on (and in) the substrate. In fact, they thrive almost anywhere that is wet, even if only for a brief period! They are thus of proven value for interpreting geologic age, depth, salinity and other parameters of sedimentary rocks (Maddocks, 1992).

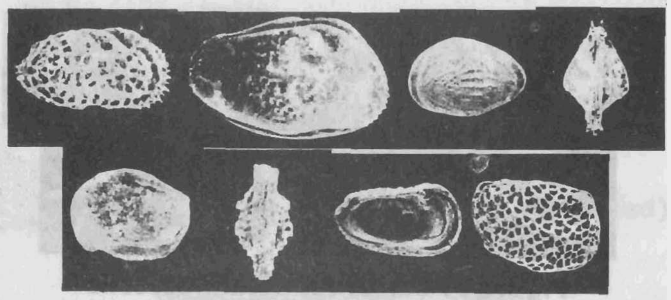


Figure 10: Ostracodes

(06.) **Radiolarians** are tiny holoplanktonic protozoans that live exclusively in the ocean and form part of the zooplankton. They thus form an important part of the marine food web. The **Polycystine** radiolarians form transparent skeletons of pure opal (i.e. silica) and are therefore more resistant to dissolution in seawater and hence more commonly preserved in the fossil record. Radiolarians have such a good fossil record because their silica skeletons preserve so well. The **Polycystina** may be divided into two suborders the **Spumellaria** and the **Nassellaria.** They are wholly marine and the most relatively commonly preserved and therefore studied members of the Subclass **Radiolaria.**

Radiolarian skeletons are amazingly complex (**Figure 11**) and can either be spherically symmetrical (i.e. the **Spumellarians**), or bilaterally symmetrical (the **Nassellarians**). They have spines extending from the main body, which increase their surface area (and thus resistance to falling in the water column), without greatly increasing overall weight. Some have oil globules as well.

Their size usually ranges from 20 to 400 μm.

Radiolarians have existed since Cambrian times (540 million years ago). Since then, different types and amounts of radiolarians have dominated different eras. Geologists now use this information in geological mapping. They are particularly abundant and diverse in equatorial latitudes especially in areas of upwelling. They are also common in subpolar seas. They are major contributors to deep-sea oozes. Limestone, chalk and radiolarian chert deposits around the world are largely formed of radiolarian deposits from the Mesozoic and Early Cenozoic eras (250 - 65 million years ago).

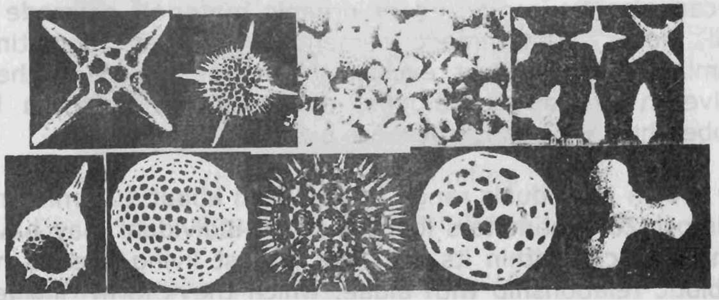


Figure 11: Radiolarians (Individuals and Assemblages)

(07.) **Silicoflagellates** (**Figure 12**) are planktonic marine protists (unicellular heterokont algae) that are both photosynthetic and heterotrophic (McCartney, 1993). Their internal silica skeletons are composed of a network of bars and spikes arranged to form an internal basket and they resemble those of radiolarians but are generally much less complex (Encyclopedia Wikipedia, 2005). Silicoflagellate skeletons usually comprise one to two percent of the siliceous component of marine sediments; they are thus much less abundant than diatoms. However, they are widely distributed throughout the world ocean They have been in existence since the Cretaceous.

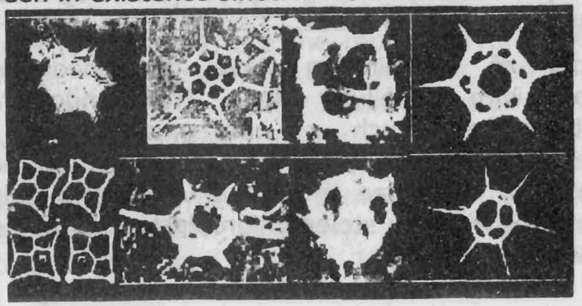


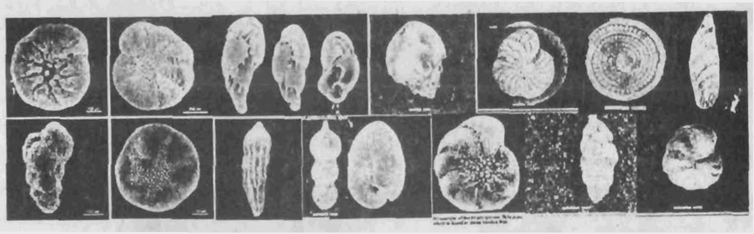
Figure 12: Silicoflagellates

(08.) **Foraminifera** (**Figure 13**) are a large group of amoeboid protists with reticulating pseudopods, fine strands that branch and merge to form a dynamic net. They include some of the simplest of the Protozoa with respect to their cellular organisation. However, the majority create skeletons of incredible beauty and structural complexity. They produce shells that are referred to as **tests** because in some forms the protoplasm covers the exterior of the shell. The tests have either one or multiple chambers, some becoming quite elaborate in structure. Their tests are, in the modern day, most often made of calcium carbonate (calcareous), but can also be composed of organic material, or made up of small pieces of sediment cemented together (agglutinated). Foraminifera are almost exclusively marine, although they can survive in brackish conditions, and are very common in the meiobenthos. However, a few are planktonic.

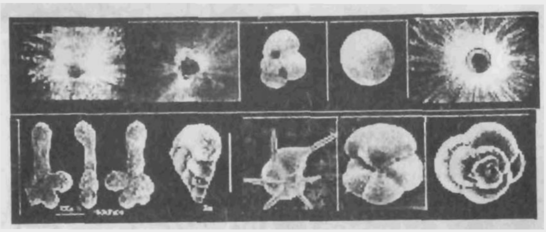
Fully grown individuals range in size from about 100 micrometers to almost 20 centimeters long. A single individual may have one or many nuclei within its cell. The largest living species have a symbiotic relationship with algae, which they "farm" inside their shells. Other species eat foods ranging from dissolved organic molecules, bacteria, diatoms and other single celled phytoplankton, to small animals such as copepods. They move and catch their food with a network of thin extensions of the cytoplasm called **reticulopodia, similar to the pseudopodia of an** amoeba, although much more n**umerous and thinner.**

About 750 000 foraminiferal species are recognized (Loeblich and Tappan, 1964, 1988; Boersma, 1978, MIRACLE, 2005), both living and some fossil. The form of the test is the primary means by which foraminferans are identified and classified. Fossil foraminifera have been recovered from as far back as the Cambrian period but, as a group, did not begin to extensively radiate until the Carboniferous.

A number of foraminifera have developed endosymbiotic interactions with unicellular algae. Their endosymbionts span divergent lineages such as the green algae, red algae, dinoflagellates, chrysophytes, and diatoms. Some sequester chloroplasts of the algae they feed upon, and gain food from photosynthesis in these stolen chloroplasts, a condition known as kleptoplasty.



(a) Benthic Foraminifera



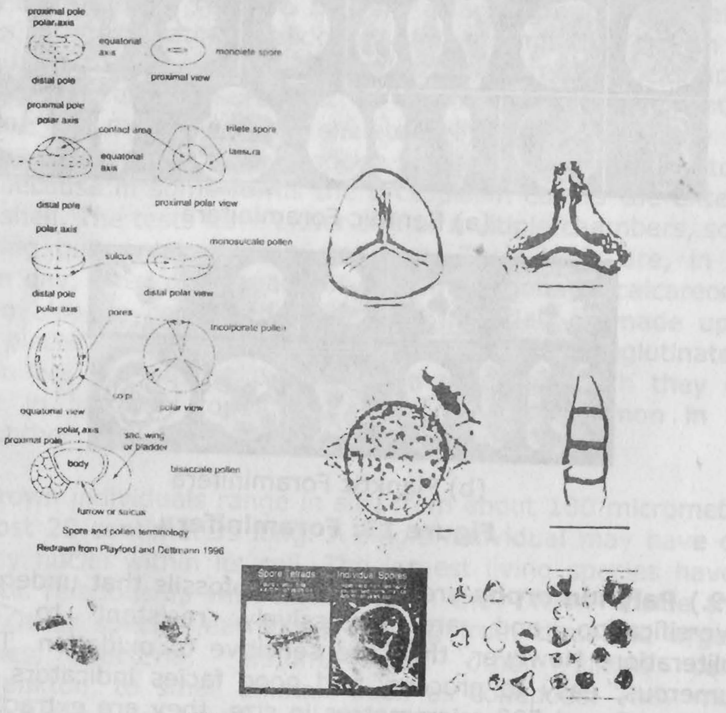
(b) Planktic Foraminifera

Figure 13: Foraminifera

(09.) **Palynomorphs** are organic microfossils that undergo rapid diversification and are excessively resistant to geologic obliteration. However, they are sensitive to oxidation. They are numerous, easy to process, and good facies indicators. Usually between 5 and 500 micrometres in size, they are extracted from rocks and sediments physically, by wet sieving, often after ultrasonic treatment, and chemically, by using chemical digestion to remove the non-organic fraction (*e.g.* using hydrochloric acid (HCl) is used to digest carbonate minerals, and hydrofluoric acid (HF) is used to digest silicate minerals in suitable fume cupboards in specialist laboratories). Samples are then mounted on microscope slides and examined using light microscopy or scanning electron microscopy.

The most commonly used palynomorphs are:

(09a.) **Spores** (**Figure 14**) are the reproductive bodies of non-flowering "lower" plants (algae, fungi, mosses, ferns). They are spheroidal, tetrahedral or elongate and generally biconvex or planoconcave. Their surface sutures, scars or laesurae are monolete, trilete or alete (with no suture). They display heterospory with two types by some plant of different size microspores- male (<200 microns) and megaspores-female, many 500 to 2000 microns (Traverse, 1988; Bignot, 1985).



Spore and pollen terminology

Redrawn from Playford and Dettmann 1996

Figure 14:Spores

(09b.) **Pollen** (**Figure 15**) are the male germinant bodies of seed plants (microgametophytes) and gymnosperms. They are thus obtained from the anthers of angiosperms (flowering plants) and microsporangia of gymnosperms (pines, spruce, firs). Generally 20-80 microns but rarely <10 or >200 microns, they have an age range of Pennsylvanian (Lower Carboniferous) to Recent. The first gymnosperm pollen evolved during the Carboniferous while the first angiosperm pollen debuted during the Cretaceous. In their classification, shape is the most important criterion while sculpture is next in importance.

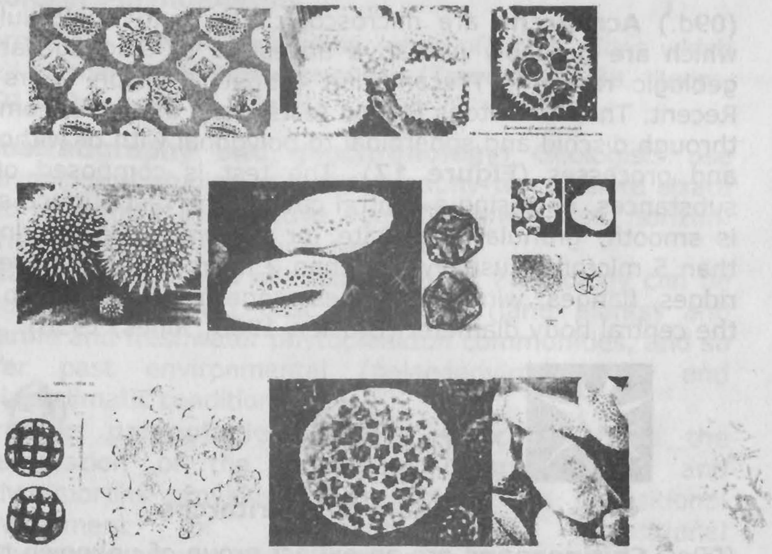


Figure 15: Pollen

09c.) (**Dinoflagellates** are biflagellate, autotrophic, photosynthetic unicellular algae, 5 µm to 2 mm long with a vegetative stage and a encysted stage or resting cyst called **dinocysts** (**Figure 16**). The have existed since the Permian. However, they became important in the fossil record only since the Early Jurassic (Liassic). The earliest calcareous and siliceous forms debuted respectively in the Upper Jurassic and Early Tertiary. Along with acritarchs, they dominate the open marine environment.

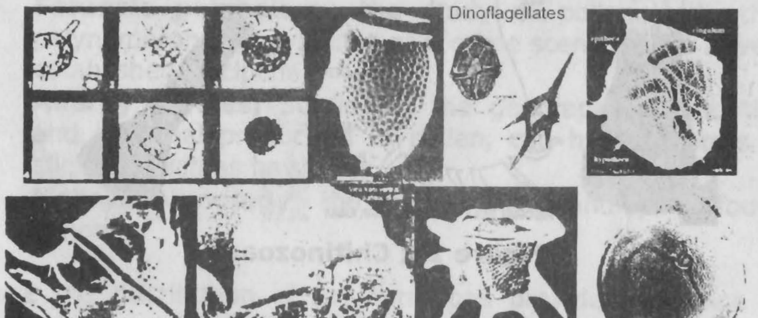


Figure 16: Dinoflagellates (Dinocysts)

(09d.) **Acritarchs** are microscopic apparently unicellular cysts, which are probably primative ancestors to dinoflagellates. Their geologic range is Precambrian (about 2 billion years ago) to Recent. Their skeletons (called tests) vary in shape from fusiform through discoid and spheroidal to polygonal with or without spines and processes (**Figure 17**). The test is composed of organic substances, enclosing a central cavity. The test surface sculpture: is smooth, granular, punctate, or perforate. Sculpturing is less than 5 microns, (usually less than 2 microns). When present, the ridges, flanges, wings, or spines range from over 10 to 20 % of the central body diameter (Brasier, 1980; Jones, 1956).

Figure 17: Acritarchs

(09e.) **Chitinozoans** are an extinct group of unknown taxonomic affinity with a hollow organic walled skeleton, which is radially symmetrical about the longitudinal axis. They ranged from Ordovician to Devonian. The flask-shaped chamber (**Figure 18**) possesses a shoulder and flank, an oral tube, and a neck. Its base has a central pore and concentric ribs. Its basal margin sometimes bears appendices. Chitinozoans are easily identified by their colonial tendency, shape, and nature of basal margin, internal structure, and size.

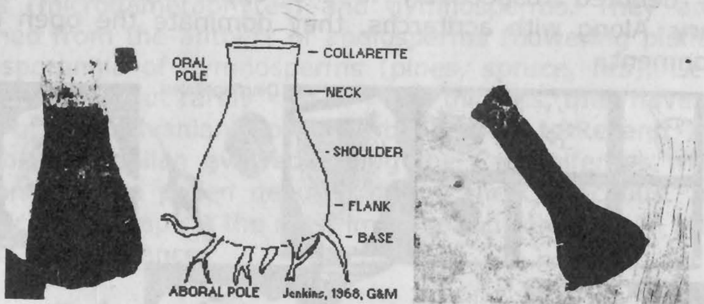


Figure 18: Chitinozoans

Applications of Palynomorphs

Palynomorphs are used for a diverse range of applications which are related to many scientific disciplines (Traverse, 1988, Moore, *et al.*, 1991). These are as follows:

- **Biostratigraphy and geochronology:** Geologists use palynological studies in biostratigraphy to correlate strata and determine the relative age of a given bed, horizon. formation or stratigraphical sequence.
- **Palaeoecology and climate change:** Palynology can be used to reconstruct past vegetation (land plants) and marine and freshwater phytoplankton communities, and so infer past environmental (palaeoenvironmental) and palaeoclimatic conditions.
- **Organic palynofacies studies,** which examine the preservation of the particulate organic matter and palynomorphs provides information on the depositional environment of sediments and depositional palaeoenvironments of sedimentary rocks.
- **Geothermal alteration studies** examine the colour of palynomorphs extracted from rocks to give the thermal alteration and maturation of sedimentary sequences, which provides estimates of maximum palaeotemperatures.
- **Limnology studies:** Freshwater palynomorphs and animal and plant fragments, including the prasinophytes and desmids (green algae) can be used to study past lake levels and long term climate change.
- Taxonomy and evolutionary studies.
- **Forensic palynology:** the study of pollen and other palynomorphs for evidence at a crime scene is also a well-established discipline.
- **Allergy studies:** Studies of the geographic distribution and seasonal production of pollen, can help sufferers of allergies such as hay fever.
- **Melissopalynology** - the study of pollen and spores found in honey.

Because the distribution of palynomorpns provides evidence of stratigraphical correlation through biostratigraphy and palaeoenvironmental reconstruction, one common and lucrative application of palynology is in oil and gas exploration. Palynology also allows scientists to infer the climatic conditions from the vegetation present in an area thousands or millions of years ago. This is a fundamental part of research into climate change.

THE NIGERIAN ECONOMY:

One of the most commonly used indicators for expressing the wealth or poverty of nations is its Gross National Product (GNP). The sum of the value of a nation's output of goods and services, it is calculated by adding up the amount of money spent on a country's final output of goods and services or by totaling the income of all its citizens, including the income from factors of production used abroad. The measure of progress, or lack of it, is indicated by the GNP growth rates, i.e., the percentage change in GNP over a period of time, usually a year. The average income of a country's citizens is contained in the GNP per capita, which is the GNP divided by the population. Nigeria's current Gross National Product (GNP) is US$ 43,286 million and its per capita Gross Domestic Product (GDP) is US$ 310. The Gross Domestic Product (GDP) is the value of goods and services produced in an economy during a period of time irrespective of the nationality of the people who produce the goods and services. It is calculated without making deduction for depreciation. It is obtained by valuing outputs of goods and services at market prices and then aggregated. It should be noted that only goods used for final consumption or investment goods (capital) or changes in stocks are included. It is a measure of the total amount of money changing hands in a nation.

Table One below shows some statistics on Nigeria's productivity in the various economic sectors. It indicates that in 2004, the Agricultural sector constituted 30.8 % of Nigeria's Gross Domestic Product (GDP) while the Industry and Services constituted 43.8 % and 25.4 % respectively. It also shows that the major industries are **crude oil**, **coal**, **tin**, **columbite**, palm oil, peanuts, cotton, rubber, wood, hides and skins, textiles, **cement and other construction materials**, food products, footwear, chemicals, fertilizer, printing, ceramics, and **steel**.

Table One: Statistics on Nigeria' Productivity (mainly for 2004)

GDP:	Purchasing power parity – $114.8 billion (2004 est.)
GDP - real growth rate:	7.1% (2004 est.)
GDP - per capita:	Purchasing power parity – $900 (2004 est.)
GDP - composition by sector:	*Agriculture:* 30.8% *Industry:* 43.8% *Services:* 25.4% (2004 est.)
Investment (gross fixed):	27.7% of GDP (2004 est.)
Population below poverty line:	60% (2000 est.)
Household income or consumption by percentage share:	*Lowest 10%:* 1.6% *Highest 10%:* 40.8% (1996-97)
Distribution of family income - Gini index:	50.6 (1996-97)
Inflation rate (consumer prices):	13.8% (2004 est.)
Labor force:	54.36 million (2004 est.)
Labor force - by occupation:	Agriculture 70%, Industry 10%, Services 20% (1999 est.)
Budget:	*Revenues:* $8.026 billion *Expenditures:* $11.09 billion,
Public debt:	28.6% of GDP (2004 est.)

Agriculture - products:	Cocoa, peanuts, palm oil, corn, rice, sorghum, millet, cassava (tapioca), yams, rubber; cattle, sheep, goats, pigs; timber; fish
Industries:	Crude oil, coal, tin, columbite, palm oil, peanuts, cotton, rubber, wood, hides and skins, textiles, cement and other construction materials, food products, footwear, chemicals, fertilizer, printing, ceramics, steel.
Industrial production growth rate:	2.3% (2004 est.)
Electricity - production:	15.67 billion kWh (2001)
Electricity - consumption:	14.55 billion kWh (2001)
Electricity - exports:	20 million kWh (2001)
Electricity - imports:	0 kWh (2001)
Oil - production:	2.256 million bbl/day (2004 est.)
Oil - consumption:	275,000 bbl/day (2001 est.)
Oil - exports:	NA (2001)
Oil - imports:	NA (2001)
Oil - proved reserves:	27 billion bbl (2004)
Natural gas - production:	15.68 billion cu m (2001 est.)
Natural gas - consumption:	7.85 billion cu m (2001 est.)
Natural gas - exports:	7.83 billion cu m (2001 est.)
Natural gas - imports:	0 cu m (2001 est.)
Natural gas - proved reserves:	4.007 trillion cu m (2004)
Current account balance:	$1.439 billion (2004 est.)
Exports:	$21.8 billion f.o.b. (2004 est.)
Exports - commodities:	Petroleum and petroleum products 95%, cocoa, rubber
Exports - partners:	US 38.3%, India 9.9%, Brazil 6.8%, Spain 6.2%, France 5.6%, Japan 4% (2003)
Imports:	$14.54 billion f.o.b. (2003 est.)
Imports - commodities:	Machinery, chemicals, transport equipment, manufactured goods, food and live animals
Imports - partners:	US 15.6%, UK 9.6%, Germany 7.3%, China 7.2%, Italy 4.3% (2003)
Reserves of foreign exchange and gold:	$7.128 billion (2004 est.)
Debt - external:	$31.07 billion (2004 est.)
Economic aid - recipient:	IMF $250 million (1998)
Currency:	naira (NGN)
Currency code:	NGN
Exchange rates	naira per US dollar - 129.222 (2003),

From Table One has been extracted the contents of Table Two, which indicate products of geological exploration and exploitation.

Table Two: Products of Geological Investigation (particularly Crude Oil and Gas)

Industries:	crude oil, coal, tin, columbite, cement and other construction materials
Oil - production:	2.256 million bbl/day (2004 est.)
Oil - consumption:	275,000 bbl/day (2001 est.)
Oil - exports:	NA (2001)
Oil - imports:	NA (2001)
Oil - proved reserves:	27 billion bbl (2004)
Natural gas - production:	15.68 billion cu m (2001 est.)
Natural gas - consumption:	7.85 billion cu m (2001 est.)
Natural gas - exports:	7.83 billion cu m (2001 est.)
Natural gas - imports:	0 cu m (2001 est.)
Natural gas - proved reserves:	4.007 trillion cu m (2004)
Current account balance:	$1.439 billion (2004 est.)
Exports:	$21.8 billion f.o.b. (2004 est.)
Exports - commodities:	Petroleum and petroleum products 95%, cocoa, rubber

A major feature of Nigeria's economy since the 1970s has been its dependence on petroleum, which accounted for 87 percent of export receipts and 77 percent of the federal government's revenue in 1988. In 2004, petroleum and petroleum products accounted for 95 % of Nigeria's foreign exchange earnings, almost half of Nigeria's gross domestic product (GDP), and nearly 80% of government revenues.

An OPEC member, Nigeria is the world's eighth largest oil producer. Nigeria is a major oil supplier to Western Europe and was the 5th largest supplier of crude oil to the United States in 2003.

Estimates of Nigeria's proven oil reserves range from 25 billion (*Oil and Gas Journal*) to 35.2 billion barrels (OPEC). The majority of these reserves are found in relatively simple geological structures along the country's coastal Niger River Delta, but newer reserves have been discovered in deeper waters offshore Nigeria (**Figure 19**). At least 200 other fields are known to exist and contain undisclosed reserves. Nigeria's crude oil reserves have gravities ranging from 21° API (American Petroleum Institute) to 45° API. Nigeria's main export crude blends are Bonny Light (37° API) and Forcados (31° API). Approximately 65% of Nigerian crude oil production is light (35° API or higher) and sweet (low sulfur content).

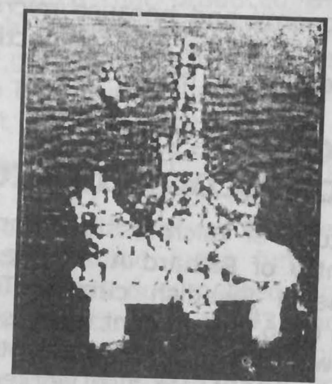


Figure 19: An Oil Rig / Platform Offshore Nigeria

Nigerian crude oil production averaged 2.1 million barrels per day (bbl/d) in 2003. In June 2004, Nigeria's OPEC crude oil production quota was raised to 2.14 million bbl/d as of August 1, 2004, as part of OPEC's two-stage plan to increase production in the face of record-high crude oil prices.

In addition to crude oil, Nigeria has an estimated 159 trillion cubic feet (Tcf) of proven natural gas reserves, giving the country one of the top ten natural gas endowments in the world. Due to a lack of utilization infrastructure, Nigeria still flares about 40% of the natural gas it produces and re-injects 12% to enhance oil recovery. Official Nigerian policy is to end gas flaring completely by 2008. The World Bank estimates that Nigeria accounts for 12.5% of the world's total gas flaring. Shell estimates that about half of the two billion cubic feet of associated gas (i.e., gaseous byproducts of oil extraction) is flared in Nigeria annually.

Nigeria's oil refining and downstream sectors also contribute immensely to the nation's economy in terms of jobs, infrastructure development etc.

Contribution of Microfossils to the Economy.

Microfossils are the most important group of all fossils — they are extremely useful in age-dating, correlation and paleoenvironmental reconstruction, all important in the oil, mining, engineering, and environmental industries, as well as in general geology. Billions of dollars have been made on the basis of microfossil studies. Since the oil industry contributes so much to the Nigerian economy and because microfossils contribute so immensely to the discovery and production of oil, they are indispensable to the Nigerian economy.

STUDY OF MICROFOSSILS (MICROPALEONTOLOGY) IN NIGERIA:

In Nigeria, the study of microfossils commenced on arrival (in 1950) in the country of Richard A. Reyment, an Australian who eventually became a Swedish citizen. The first professor of Geology in Nigeria (1963), Reyment made significant contributions to this field as well as to macropaleontology (e.g. Reyment, 1955c, 1960a, b, c, 1965). He also worked in collaboration with other eminent foreign micropaleontologists (e.g. William Berggren) on Nigerian materials (*cf.* Berggren, 1960). Subsequently, several Nigerian micropaleontologists emerged. Important contributions of such micropaleontologists outside this University include those of Fayose (1970, 1979), Petters (1979, 1982, 1983), Lawal and Moullade (1986), Billman (1992), Ozumba (1999) etc.

Mr. Vice-Chancellor Sir, I started my training as a Micropaleontologist here in Ilé-Ifè in 1973 when Professor O. S. Adégòkè, in a Part Three course, taught us virtually all aspects of the protozoan group called Foraminifera and invited the world-renowned Nigerian palynologist (Professor Mrs. Adébísí Sówùnmi) from the University of Ìbàdàn to introduce Palynology to my class.

Since then, I have had the unusual good fortune of being associated with some of the greatest minds in micropaleontology in this country right here in the Department of Geology at Ilé-Ifè. This exceptional team, which was built over the years, has consisted of Professors Adégòkè, Ivan de Klasz, M. Babajide Salami, C. A. Kogbe and J. I. Nwachukwu (before he changed over to the greener pastures of petroleum geology) and Drs. Jan du Chêne and E. I. Enu.

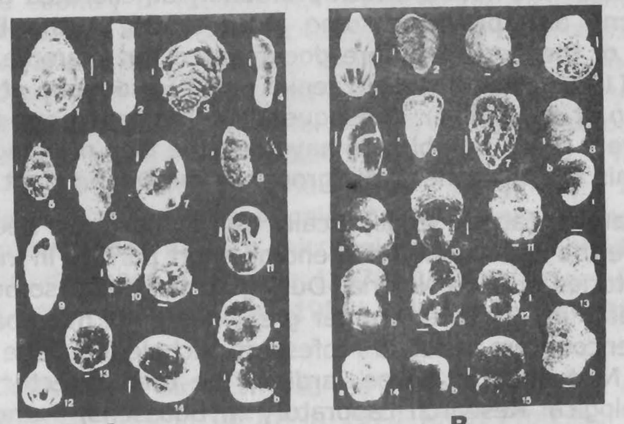
Exceptional micropaleontology publications that emanated from this formidable team over the years (Jan du Chêne, 1977; Adégòkè, 1978; Ako *et al.*, 1980; Kogbe and Mehes, 1986; Salami, 1982a,b, 1985, 1990; Oboh and Salami, 1989; Nwachukwu *et al.*, 1992) remain highly relevant today to the study of microfossils in Nigeria. The quality of these publications buttressed the thoughts aptly expressed earlier by a modern philosopher that ***"The best way to attain respect is to produce the work of excellence"***. In addition to engaging in the painstaking research that produced these publications, the team has thoroughly trained numerous students at both the undergraduate and graduate levels. Most of these former students have gone on to do Ifè proud in their various stations in life. Some of them are present in this hall tonight.

Apart from these remarkable achievements of theirs, members of this extraordinary select group have rendered consultancy services to the nation, which profoundly ameliorated the country's economy and provided some extra funds to the Department. Some of these services are documented for example in Ako and Àjàyí (1976), Ako and Gritzaenko (1977), Adégòkè *et al.* (1980a, b), Ako *et al.*, (2004). Consequently, I am proud and at the same time very much humbled to have had the luck of being associated with this and the other virile groups in the Department.

I am largely (about 95 %) locally trained but have been fortunate to have the opportunity of spending short periods in institutes and laboratories outside Nigeria. During such foreign sojourns, it was invariably my lot to encounter great names in micropaleontology. Such encounters included Professors Michele Moullade and France Irr in Nice and Dr. Serge Jardiné, the then Director of the ELF Palynological Research Laboratory in Boussens, France (1975 to 1976), Professors Richard Reyment, William Berggren, Bilal Haq, and Björn Malmgren and Drs. Annie Skarby and Siwert Nilsson in Stockholm and Uppsala, Sweden (1979), Dr. G. W. F Herngren in Amsterdam, Netherlands (1979) and Professors Erik Flügel (of blessed memory), Christian Dullo in Erlangen and Dietrich Herm in Munich, Germany (1982) among others. I am truly a dwarf among these giants who have always inspired me to aim for excellence. Mr. Vice-Chancellor Sir, please permit me to share with you the overwhelmingly disappointing fact that up-to-date, I have not succeeded in my quest for excellence. However, I have not yet given up this pursuit. Consequently, my training as a micropaleontologist continues till this very moment. It is in this context of the truth of the fact that I am far from excellence that I will now discuss my exceedingly modest contributions to Science and the Academia.

MY CONTRIBUTIONS

My contribution to Science, which indeed is very modest, can be considered under (i) **pure** and (ii) **applied** research. My research thrust has been mainly on the **Microbiostratigraphy** and **Paleoenvironmental analyses** of rocks from various Nigerian sedimentary basins based on **foraminifera** and **palynomorphs**. I also had the opportunity of doing some work (**Figure 20**) on the Vence Basin in southeastern France (Ọdébòdé, 1976, 1978, 1982c). This work resolved the controversy that had hitherto dogged the age of the basin's Marly Formation by accurately dating it Aquitanian employing planktic foraminifera and other lines of evidence. It also established, among other things, that two marine trangressive- regressive cycles occurred in the basin during the Miocene.



A B

Figure 20: Scanning Electron Photomicrographs of the Foraminifera recovered from the Vence Basin, Southeastern France A and B (from Ọdébòdé, 1982) (The length of each white represents 40 µm)

A

1. ***Lagena hexagona* (Williamson)**
2. ***Nodosaria ovicula* d'Orbigny**
3. ***Spiroplectammina carinata* (d'Orbigny)**
4. ***Marginulina glabra* d'Orbigny**
5. ***Uvigerina subperegrina* Cushman and Kleinpell**
6. ***Uvigerina peregrina* Cushman**
7. ***Marginulina obesa* Cushman**
8. ***Marginulina fragaria* Gümbel**
9. ***Plectofrondicularia raricosta* (Karrer)**
10. ***Melonis pompilioides* (Fitchel and Moll)**
11. ***Valvulineria bradyana* (Fornasini)**
12. ***Lagena striata* (d'Orbigny)**
13. ***Baggina gibba* Cushman and To**
14. ***Pullenia bulloides* (d'Orbigny)**
15. ***Sphaeroidina bulloides* d'Orbigny**

B

1. ***Orthomorphina proxima* Silvestri**
2. ***Textularia* sp. 1**
3. ***Hoeglundina elegans* (d'Orbigny)**
4. ***Elphidium ortenburgense* (Egger)**
5. ***Cibicides lobatulus* (Walker and Jacob)**
6. ***Textularia* sp. 2**
7. ***Bolivina pseudoplicata* Heron-Allen and Earland**
8. ***Globigerinoides immaturus* Leroy**
9. ***Globigerina praebulloides* Blow**
10. ***Globigerina obesa* Bolli**
11. ***Globigerina venezuelana* Hedberg**
12. ***Globigerinoides trilobus* (Reuss)**
13. ***Globigerina ciperoensis* Bolli**
14. ***Globorotalia nana* Bolli**
15. ***Globigerinoides primordius* Blow and Banner**

In order to obtain reliable microbiostratigraphic and paleoenvironmental deductions, I have had to undertake detailed taxonomic studies on the microfossils recovered from my rock samples. These studies have partly led to the discovery and erection of new foraminifera and palynomorph species and documentation of already established ones as well as the rectification of erroneous systematic placement of some taxonomic groups of the **Order Foraminiferida** (Ọdébòdé and Skarby, 1980; De Klasz and Ọdébòdé, 1982; Ọdébòdé, 1982b, 1983a, b; Ọdébòdé and Salami, 1984; Ọdébòdé, 1986a, b, c, d; 1987a, b). The new species erected, described in detail, and illustrated mainly with Scanning Electron Photomicrographs (**Figures 21 - 26**) include ***Ariadnaesporites nigeriensis*** (**Figure 21**), ***Heterohelix calabarflanki, H. ivandeklaszi, H. nkporoensis,*** (**Figure 22**) and ***H. reymenti*** (**Figure 23**), ***Gabonita centrocostata, G. nigeriensis,*** and ***G. quadrata*** (**Figure 24**), ***Hedbergella dessauvagiei*** and ***H. sundaypettersi*** (**Figure 25**), and ***Marginotruncana fayosei*** (**Figure 26**). Moreover, another study (Ọdébòdé and others, 1996) for the first time ever, recorded a nannofossil microflora from the argillaceous strata exposed at the Ṣàgámù Limestone quarry consisting of 45 species belonging to nine families.

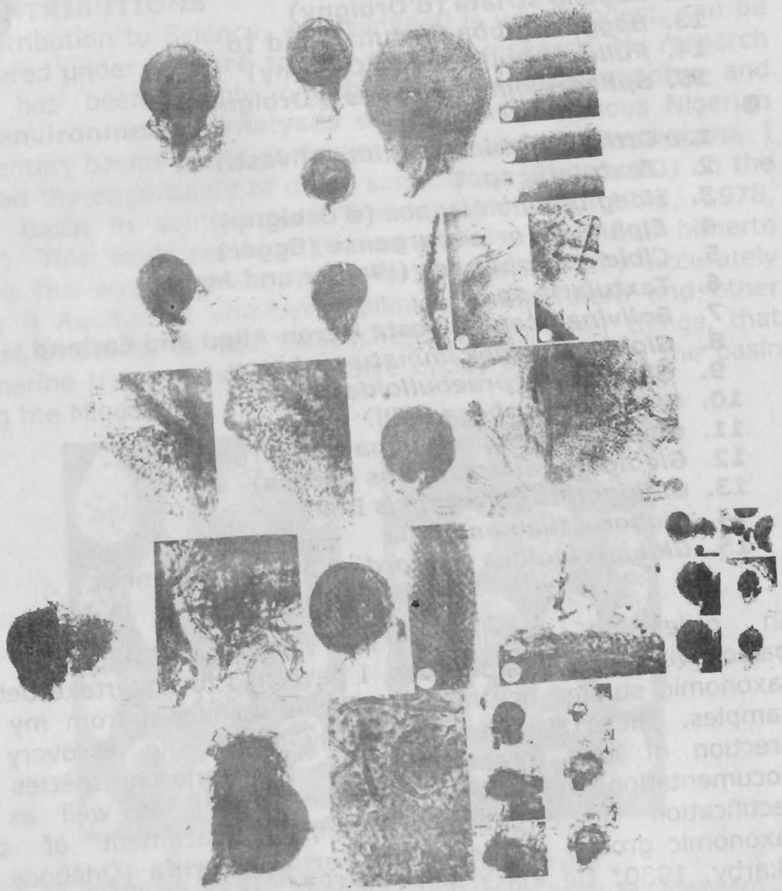


Figure 21: ***Ariadnaesporites nigeriensis*** (Ọdébòdé and Skarby and associated Miospores)

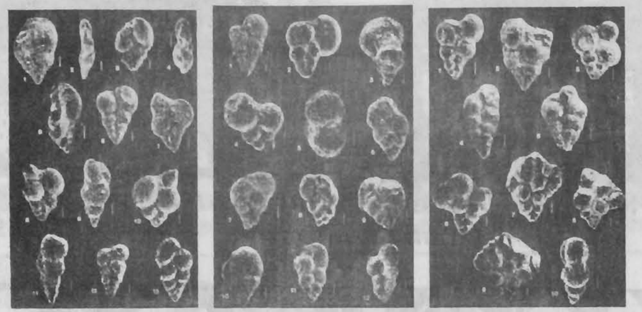


Figure 22: Heterohelicidae from the Calabar Flank, Nigeria

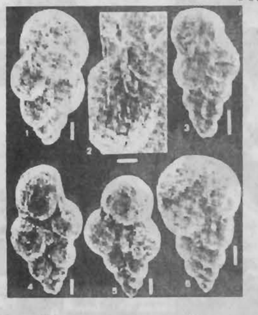


Figure 23a: *H. reymenti*

Figure 23b: *Afrobolivina afra*

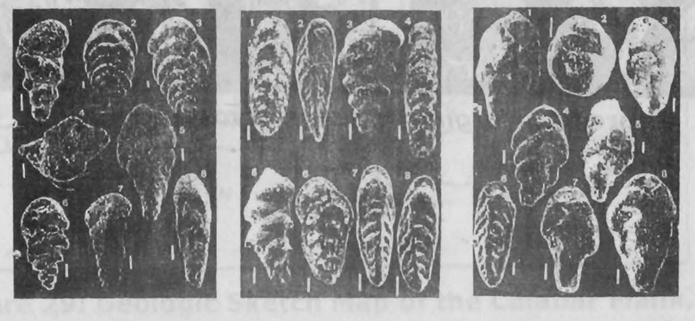


Figure 24: ***Gabonita* species from Nigeria** (New and already established forams).

Figure 25: *Hedbergella calabarflanki* and *H. sundaypettersi*

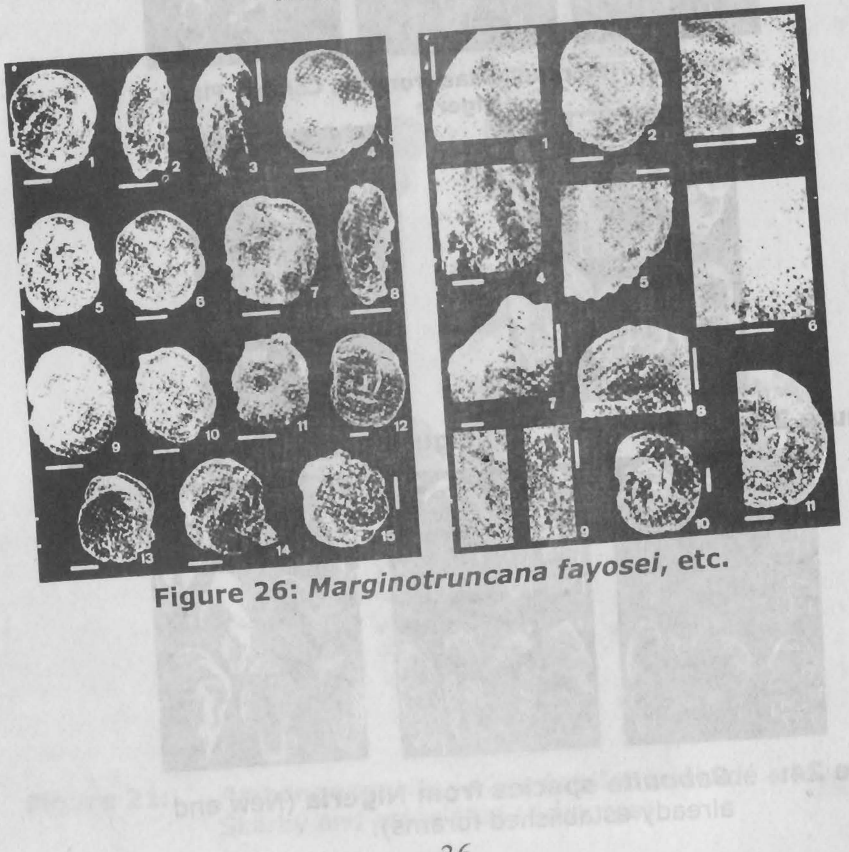
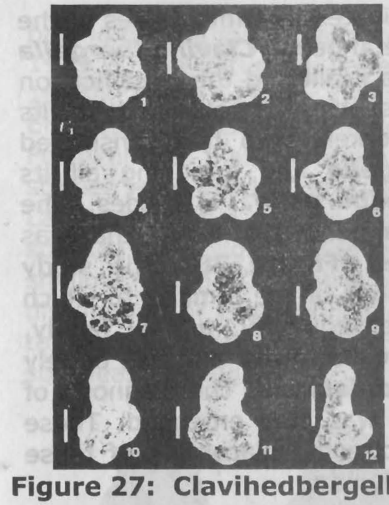


Figure 26: *Marginotruncana fayosei*, etc.



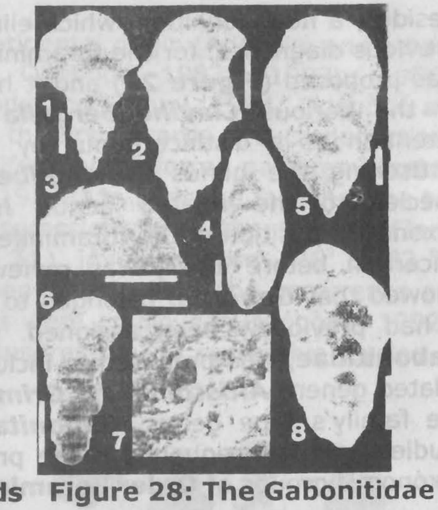


Figure 27: Clavihedbergellids Figure 28: The Gabonitidae

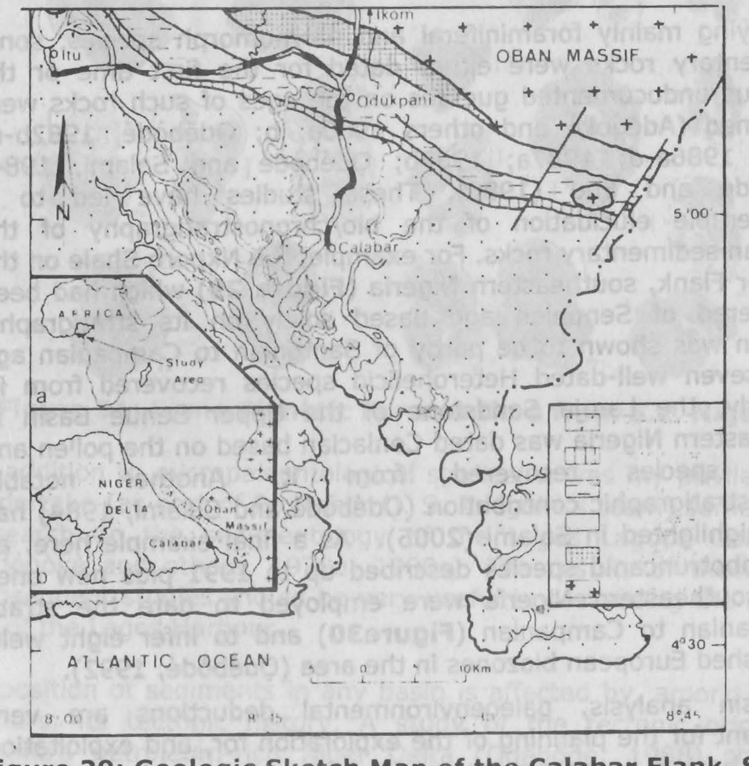


Figure 29: Geologic Sketch Map of the Calabar Flank, SE Nigeria

Besides, a new definition, which eliminates the ambiguities in the previous diagnoses, for the foraminiferal genus ***Clavihedbergella*** was proposed (**Figure 27**) and it has facilitated the classification of the various ***Clavihedbergella*** species. It also led to its retention as a distinct genus by workers who had considered jettisoning the genus ***Clavihedbergella*** and assigning all its species to the related genus ***Hedbergella***. Besides, the taxonomic position of the foraminiferal genus ***Gabonita***, that was uncertain before 1987, was reviewed (**Figure 28**). The study showed that ***Gabonita*** belonged to none of the families to which it had previously been assigned. Consequently, a new family, **Gabonitidae**, was proposed to include ***Gabonita*** and two closely related genera ***Altistoma*** and ***Grimsdaleinella***. The diagnosis of the family's type genus, ***Gabonita***, was also emended. These studies have consequently made precise the placement of these taxonomic groups of **Order Foraminiferida**.

Employing mainly foraminiferal and palynomorph species, some sedimentary rocks were either dated for the first time or the previous undocumented guesses on the ages of such rocks were confirmed (Adégòkè and others 1980a, b; Ọdébòdé, 1982b-d; 1983; 1986a-d; 1987a; 1987b; Ọdébòdé and Salami, 1984; Ọdébòdé and Enu (1986). These studies have led to a considerable elucidation of the bio/chronostratigraphy of the Nigerian sedimentary rocks. For example, the Nkporo Shale on the Calabar Flank, southeastern Nigeria (**Figure 29**) which had been considered of Senonian age based solely on its stratigraphic position was shown to be partly of Santonian to Campanian age from seven well-dated Heterohelicid species recovered from it. Similarly, the Lamja Sandstone of the Upper Benue Basin in northeastern Nigeria was dated Coniacian based on the pollen and spore species recovered from it. Another notable chronostratigraphic contribution (Ọdébòdé and Salami, 1984) has been highlighted in Salami (2005). As a final example here, all the Globotruncanid species described up to 1991 plus new ones from southeastern Nigeria were employed to date the strata Cenomanian to Campanian (**Figure30**) and to infer eight well-established European biozones in the area (Ọdébòdé, 1992).

In basin analysis, paleoenvironmental deductions are very important for the planning of the exploration for, and exploitation of, the basin's economic resources. I have thus endeavoured to deduce the depositional environments of all the sedimentary rocks studied to date using mainly foraminifera for the marine ones and palynomorphs for those of continental origin (Adégòkè and others, 1979 – the Bitumen paper; Ọdébòdé, 1983a, 1983b; 1986a, 1986b, 1987a; 1992a; Ọdébòdé and Salami, 1984; Ọdébòdé and Enu, 1986). Most of these are the first records of such deductions. For example, planktic foraminiferal and inferred paleotemperature studies were used (Ọdébòdé, 1983a) to infer the fact that the two Late Cretaceous marine transgressions onto the Calabar Flank, southeastern Nigeria (**Figure 31**), involved warm (26° to 32 °C) shallow (50 to 100 metres deep) seas. Also, the occurrence and distribution of Globotruncanids were employed (Ọdébòdé, 1992a) to deduce three marine transgressive – regressive cycles in southeastern Nigeria.

Figure 31: Some Planktic Foraminifera from S.E. Nigeria

In addition to micropaleontological studies, it was my privilege to undertake (as part of Professor O. S. Adégòkè's team) some pure research on the sedimentology of the Lagos Lagoon Complex (Adégòkè and others, 1978a, 1980c). The results of these and subsequent studies should be very useful in preventing the silting up of the Lagos Harbour.

Deposition of sediments in any basin is affected by, among other factors, its tectonic history. A study of the tectonic origin of Nigeria's petroleum-rich Niger Delta (Ọdébòdé, 1988) showed conclusively that the basin could not have been plume-generated. A more likely hypothesis, involving the tearing apart of the African and South American continents along predetermined Basement weakness (mainly fracture) zones was proposed. The proposed hypothesis was buttressed with various lines of evidence.

Mr. Vice-Chancellor Sir, it is gratifying to note that in spite of my inadequacies as a researcher and despite the incompleteness of my training to date as a micropaleontologist, more than 70 % of my publications have, by a singular stroke of luck, found their way into highly reputable international journals outside Africa. Judging by the volume of the requests for reprints received from about 20 countries the world over (particularly the first world countries), it may be concluded that they have been well received by the scientific community in my discipline. They have been cited in several journal publications and in books (e.g., Batten *et al.*, 1994; Schrank, 1996; Ojo and Akande, 2004). One in particular (Ọdébòdé, 1987c) caught the attention of the greatest 20th century authorities on the taxonomy of Foraminifera, a couple, who reviewed it in their 970-page last monumental monograph on the subject (Loeblich and Tappan, 1988). Aged 86, Helen Tappan died last year ten years after her beloved husband, Alfred Loeblich Junior (1914 – 1994).

It is only a question of candour to admit openly during this inaugural lecture tonight that I have also received some criticisms from workers who did not agree with my interpretation of some of the data I collected. However, even such workers invariably admitted that the collected data themselves constituted definite contribution to knowledge (e.g., Edet and Nyong, 1994; Petters and Edet, 1996).

Distinguished Ladies and Gentlemen, part of my work (the applied research aspect), has centred on the application of Geology to the improvement of the Nigerian society. The papers on the yet unexploited bitumen deposits in southwestern Nigeria, co-authored largely with senior colleagues (Adégòkè, Ako, and others, 1979, 1980b), for example document the stratigraphy, sedimentology, microfossils, age and depositional environment of the bitumen-bearing rocks. They also suggest the possible source rocks for the bitumen and give their reserve estimates as well as their possible uses within the Nigerian context. The papers also discussed the results of the laboratory studies to determine the chemical composition of the various samples retrieved from the bitumen belt. These publications and numerous others that emanated from the Department of Geology here in Ilé-Ifè (Adégòkè *et al.*, 1979b; 1980b) will form the basis for the eventual detailed reserve estimate appraisal and exploitation of the bitumen. This will save the country hundreds of millions of Naira in foreign exchange currently expended annually on the importation of bitumen and its products.

Deposits of very high quality glass sands occur in a discontinuous belt along the generally flat-lying and swampy Atlantic coastal area in southwestern Nigeria. A study on the belt (Ọdébòdé, 1982a) indicated that the glass sand occurrence had not been taken into consideration in land use there. This publication thus made a case for the urgent need for a developing country like Nigeria to carefully plan land use in the area taking into consideration the deposits of this very important raw material and other factors such as geomorphology, climate, soil type and engineering geology.

Most of Nigeria's (and indeed the entire world's) energy supply is at present obtained from petroleum, whose known reserves may not last another century. It is thus necessary to find alternative energy sources e.g., ocean and tidal waves. An appraisal of the shallow water currents operating along the Nigerian coast (Ọdébòdé, 1979) showed that vast quantities of energy are stored in them. The fact that the energy stored in similar currents has been successfully harnessed in France, Russia and some other developed countries (Hubbert, 1969; Gray and Gashus, 1972) show that this energy is exploitable. The 1979 paper thus made a case for the commencement of detailed systematic studies on the country's coastal waves. This and other similar calls by well-meaning Nigerians have, unfortunately, been ignored by the powers that be, to the country's peril. Consequently, uncontrolled coastal waves have, from time to time, wrought havoc by eroding the beaches and nearby roads and undermining the beachfront buildings. A good example is the Ahmadu Bello Way / Bar Beach area of the Lagos coastline. This has cost the nation enormous amounts of money that could have been better spent.

Scanning Electron Microscopy is essential to the modern taxonomic studies of microfossils as well as to other Geology disciplines. Through the foresight of its Nigerian pioneers (Professors Adégòkè and Káyòdé), the Department of Geology acquired a Scanning Electron Microscope in 1976 and hired a French technician (Monsieur Etienne Gilbert de Vautibault) to operate it. After his departure from Nigeria in the early 1980s, the microscope broke down and could not be repaired by local expertise. Consequently, in order to properly study and illustrate many of my specimens, I had to travel to Erlangen and Munich, Germany thanks to a fellowship granted by the German Academic Exchange Service (D. A. A. D.) and the assistance rendered by Professors A. A. Káyòdé, Gerd Tietz, Erik Flügel, Christian Dullo and Dietrich Herm. It is thus highly pleasant to note that the University's Central Science Laboratory has acquired a modern computerized Scanning Electron Microscope. In a highly organized and well-attended workshop on the use of the microscope, I was opportuned to have been invited to participate as a resource person by the Director of the Laboratory (Professor K. A. Ako-Nai) and the Organizing Committee members. In the paper presented there (Ọdébọdé, 2002), this invaluable tool in the Geological Sciences was thoroughly discussed.

Similarly, I was lucky to have been invited as a resource person to the UNESCO-sponsored National Training Workshop on Environmental Degradation, Reclamation, Conservation and Pollution Prevention held in Adó-Èkìtì in August 2004. The paper presented at this workshop (Ọdébọdé, 2004) thanks in part to literature provided by Professor M. B. Salami and Dr. O. O. Ocan espoused the pollution effects of indiscriminate mining operations in Nigeria on the environment.

Mr. Vice-Chancellor Sir, one of the fundamental duties of an academic is the training of students both at the undergraduate and graduate levels. In my 28 years as an academic staff at various levels in this great institution, I have, under the tutelage of my extraordinary senior colleagues and the support of the others, singly taught or shared in the teaching, of eighteen undergraduate courses and three postgraduate ones.

It has also being my good fortune to have supervised more than fifty B. Sc. (Honours) Thesis projects. In the Department of Geology, students are actively encouraged to interact with their thesis project supervisors as well as all other academic staff. It is as a result of this progressive policy (of interaction) that four of the students whose projects I supervised won the first prize of the Nigerian Mining and Geosciences Society / ExxonMobil Awards for the best Undergraduate Geosciences theses in Nigerian Universities for four consecutive years (2002 to 2005). These theses (Jọláawo, 2001; Ódèlé, 2002; Akíndípè, 2003; Agbéjúlé, 2004) are a source of pride to Nigeria's Geoscientific Community and of inspiration to the current undergraduate students in the Department.

At the graduate level, I co-supervised (with Professor M. B. Salami as the main supervisor) an M. Sc. thesis project, which was successfully concluded in 1984. This constituted my first venture into graduate supervision in Ile-Ife. The thesis (Òjó, 1984) has the distinction of having been the only M. Sc. dissertation in the Department (of Geology) to date that was concluded within 18 months.

Thereafter, I also had the privilege of designing a Cand. Scient. Thesis project for a Nigerian student at the University of Oslo, Norway and in collaboration with the student's supervisor, Professor Dale, guided the project to a successful completion in May 1986.

The Department's progressive policy on project supervision has also, over the years, enabled me to contribute my "widow's mite" to the prosecution of other graduate projects of which I was not directly involved as a supervisor. Finally, I currently have the privilege of supervising two M. Phil. / Ph. D. candidates.

I have also, over the years participated in departmental consultancy projects, which are relevant to my area of interest and specialization in Geology. Apart from these, three oil-servicing companies have sought my expertise from time to time whenever they had knotty (non-routine) problems to solve.

Finally, I was opportune to have worked in the Chevron laboratory in Lagos during my sabbatical leave from 1996 to 1997, thanks to the help of Messrs Bayo Akinpelu and Emmanuel Adokpaye. In addition to reviewing the reports submitted by oil-servicing companies, I also worked on the microbiostratigraphy and sequence stratigraphy of several wells. Sequence stratigraphy is the modern tool employed in the search for, and production of petroleum (Van Wagoner *et al.*, 1988; Galloway, 1989) and microfossils are indispensable to its success. My work in Chevron was highly rewarded but cannot be reviewed here for propriety reasons.

RECOMMENTATIONS

Mr. Vice-Chancellor Sir, please permit me to air my views on certain aspects of life in this University in particular and in the Nation in general. These views do not necessarily bear directly on tonight's lecture but this is as good as any other forum, for presenting them.

1. The problem of Inadequate Funding of University Education

It is perhaps superfluous to state that universities are currently grossly underfunded in the country. The consequences of this can be seen around the campus at Ilé-Ifè and other campuses around the country. Employers of labour also feel its adverse effects. To rectify this situation, I wish to state that Education is NOT and has never been free anywhere in the world because somebody or some organizations have had to pay the bills. In the middle 1970's the Federal Government attempted to play the role of the financier of education at all levels by taking over tertiary, secondary and primary schools in the country. It is however, glaring that it no longer wants to discharge this responsibility.

While not relenting in our efforts to persuade the governments of Nigeria to undertake this responsibility, it is imperative that we look for alternative sources of funds. This is because the University community has a responsibility for turning out fully baked graduates and this requires funds. Consequently, we must aggressively pursue consultancy as a policy. It is in this regard that the proposal written by Prof. M. B. Salami (and which is currently being developed in the Department) to establish a quarry on the University estate is opportune. If the University cannot take over the RCC Quarry situated along the Ifè – Ilésà bypass (which is on the University land), it can at least exploit the enormous volumes of rocks in one of its hills. However, in order to completely develop this and any other potentially useful proposals, the University must put aside some seed money. The seed money could also be used, in part, to finance the numerous trips to various organizations to raise money for the University.

The now fully functional Scanning Electron Microscope (SEM) in the University should be used to generate funds not only for its running and maintenance costs, but also extra funds for the University. It is thus necessary to aggressively publicize the fact that it is available here in Ilé-Ifè so that other Universities and some organizations (e.g. oil and oil-servicing companies) can avail themselves of its services instead of sending their samples abroad.

It may also be necessary for some academic departments to change their names to reflect the fact that they are relevant to the almighty oil industry in Nigeria. Doing so will undoubtedly attract funds to the University from that and related industries. Should the Federal Government really be unable to adequately fund universities, it can rectify the situation by adopting a proposal suggested in some quarters years ago. This proposal entails the assignment of one marginal oil field to each federal university in the country. The management of the operations of such fields will be the responsibility of each recipient University that will also have the proceeds thereof.

2. Dearth of Geology Lecturers

In addition to understanding this, another worrisome aspect of all Geosciences Departments in the country. It is also linked to the succession problems in these Departments. Since geologists in the industry are much better paid than their counterparts in the academia, it has been extremely difficult to attract young intelligent graduates who will rather seek employment in the oil industry in particular. This situation must change in view of the relevance of Geology to the nation's economy. To rectify this situation, geology lecturers should be much better remunerated. It is here proposed that a special allowance not lower than 150 % of the academics basic salary be paid to them. This will definitely attract young people to the teaching profession and ensure continuity in producing geologists for the country.

3. Dearth of Micropaleontologists

Micropaleontology is a very demanding discipline. It requires incredible amounts of time and unending patience on the part of its practitioners. It is no wonder therefore, that there are very few micropaleontologists in the country.

However, as tonight's lecture has shown, micropaleontologists are indispensable to the oil industry, the mainstay of Nigeria's economy. The only remedy that I can proffer to ameliorate this situation is to give more perks to the micropaleontologist who (please take note) is also a geologist.

4. The Image of the Ọbáfẹ́mi Awólọ́wọ̀ University

The past wonderful image of this great university was built on the realization (in the 1960s to early 1980s) of the dream of its founding fathers: academic excellence coupled with excellence in sports and all other aspects of University life. It was also enhanced by the sterling leadership qualities of its administrators and the fantastic dedication to duty on the part of the academic, administrative and technical staff. Besides, students were more mature and they knew their limits. In the past two decades, however, this image has been progressively badly dented. I wish to humbly suggest tonight that it is time to redeem the University's image and recover its lost glory.

In this regard, Mr. Vice-Chancellor Sir, I wish to leave tonight's distinguished audience with some food for thought by reciting two of my favourite quotations.

Frantz Fanon (1925-1961), a Martinique, Caribbean psychiatrist and prominent thinker of the 20th century on the issue on the psychopathology of colonization, in his book *Les Damnés de la Terre* (*The Wretched of the Earth*) said:

> ***"Each generation, out of relative obscurity, must discover its mission, fulfill it or betray it".***

The late John Fitzgerald Kennedy, the youngest elected president ever of the United States of America, partly quoting the scriptures – the Christian scriptures once said:

> ***"For of him to whom much is given, much is required, and when at some future date, the high court of history sits in judgment on each one of us, recording whether in our brief span of service, we fulfilled our responsibilities to the state, our success or failure in whatever office we hold will be measured by the answers to four questions: First – were we truly men of courage, Second – were we truly men of judgment, Third – were we truly men of integrity, and Fourth were we truly men of dedication?"***

Mr. Vice-Chancellor Sir, and members of tonight's distinguished audience, I profoundly thank you for your presence and attention.

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