NIGERIA'S MINERAL RESOURCES FOR WEALTH, INDUSTRY, INFRASTRUCTURE AND LIFE PUBLIC LECTURE DELIVERED

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PREAMBLE

I would like to begin by thanking the Chairman of the occasion, a former academic renowned geologists in its own right who has found time, within thereally buy period, and we all know that it is very busy, to accept to Chair thisevent.

The Special Guest of Honour, Arc Musa Sada is equally, if not more, a very busy man and has shown his commitment to the development of science (including the environmental science) by travelling from Abuja, to honour this invitation.

I would also like to pay tribute and remember those great scientists and illustrious men of honour, the fellows of the Academy who passed away in the last twelve months i.e. since the last general meeting of the Academy. These are Prof Oyenuga, Prof Adesola, Dr Amenechi, Prof Oladapo and of course the Grand Patron of the Academy: Alhaji Umar Musa Yar'Adua, GCFR, the former President of the Federal Republic of Nigeria.

In preparing for this lecture, I was mindful of the charge that the audience will be both scientists and non-scientists. The challenge has therefore been to steer a middle course between high falluting equations or ideas in engineering geology or geotechnical engineering my special area of interest, which might interest the fellows. The alternative is something very bland for the wider public. Both have inherent risk of sending people to sleep. The one can bore the fellows to a deserved sleep after the retreat in Cotonou for Council member (and some fellows) and lunch, the other to a less deserved sleep but that which will come from a boring afternoon lecture.

In the consideration I am easily reminded of the famous statement by Lord Rutherford about the point of a good physicist being able to explain quantum physics to his char woman (i.e. the housed cleaner). I hope there will be enough spice in the lecture that will capture your attention and keep you awake for its duration.

INTRODUCTION

This lecture is divided into two parts. The first is of general nature and provides the background to Nigeria's minerals and the second describes hat we have done about the impact of these minerals on Nigeria's development.

PART 1: SETTING THE SCENCE

What are Minerals?

1. Minerals are solid substances found within the crust of the earth with fixed chemical compositions formed by the inorganic processes of nature. They constitute the building blocks of rocks; hence rocks are referred to as aggregates of minerals. Geology is the study of the earth, its composition and the processes that are shapening the earth as recorded in the rocks. Mineral deposits are associated with specific geological environments.

Solid Minerals – A Definition

2. Solid minerals (in the Nigerian context - Mining and Minerals Act 2007) are defined as all earth resources except for all oil, gas and water. They include fuel minerals of coal, lignite and bitumen as well as the geomaterials of sand, gravel and laterite.

Importance of Solid Minerals

3. Solid minerals are very important to every nation. The weapons with which we wage wars and defend our national territory are derived from minerals. Materials for housing, national and local infrastructure are derived from minerals. Technological machineries and inventions are made with minerals, the energy with which these machines are powered are derived from fuel minerals. Agricultural fertility is dependent on minerals and importantly human and animal health on the planet depends on solid minerals (either through requirement or toxicity).

4. Solid Minerals is one of the sectors that can respond at once to the need for economic growth through wealth creation and reduction in poverty. It helps to create wealth through encouragement of foreign direct investment into the mining sector as well as large investment into industrial minerals e.g. the processing of limestone into cement.

5. At the same time it responds to poverty reduction through the improvement in the lives of artisanal small scale miners and mining communities.

Minerals and National Wealth

6. Globally the mining sector of mineral-producing countries has been a major foreign exchange earner and a provider of job opportunities for their citizens and other stakeholders. For many years, the mining sector has remained a positive core contributor to the sustainable socio-economic development of mineral-producing countries.

7. Recent economic research findings indicate that earnings from solid minerals contribute

a reasonable share of the Gross Domestic Product (GDP) of such countries as Ghana, South Africa, Australia, Canada, and the USA, among others.

8. Data for 2007, for instance, show that the mining sector contributed 5% to Ghana's GDP, accounted for 12% of its government's revenue, comprised 41% of total export earnings and employed over 500,000 people. It contributed 7% to South Africa's GDP, accounted for 12.4% of its total company tax, provided 25.2% of the country's total foreign exchange earnings and employed slightly under a million workers. For Canada it contributed $42 billion or 3% to the GDP, with mining industry payments of $8 billion to its government, constituted 19% of total exports, and provided direct employment of 363,000 people.

9. The comparable information for Nigeria' is that solid minerals have contributed a paltry 0.3% or less over the last fifteen years. Certainly we need to do something about it and I will show later in the lecture the efforts that the have been made over the last five years.

Minerals and Infrastructure

10. Geology interfaces with infrastructure in directly in two areas.

i. The application of geological principles in the understanding of engineering phenomena- Engineering Geology
ii. The production and proper use of geomaterials

In addition there are indirect interfaces e.g. the link between mining infrastructures which has always been important.

Geology in Engineering Practice

11. Engineering Geology is the application of the geologic sciences to engineering practice for the purpose of assuring that the geologic factors affecting the location, design, construction, operation and maintenance of engineering works are recognized and adequately provided for.

12. Engineering geologists investigate and provide geologic and geotechnical recommendations, analysis, and design associated with human development. The realm of the engineering geologist is essentially in the area of earthstructure interactions, or investigation of how the earth or earth processes impact human made structures and human activities.

13. Engineering geological studies may be performed during the planning, environmental impact analysis, civil or structural engineering design, value engineering and construction phases of public and private works projects, and during post-construction and forensic phases of projects. Works completed by engineering geologists include; geological hazards, geotechnical, material properties, landslide and slope stability, erosion, flooding, dewatering, and seismic investigations, etc.

14. Engineering geological studies made major contribution to the major development of In-

frastructure (Federal capital, Dams, Airports and Highways) in Nigeria during the 1975-85.

Geomaterials

15. Geomaterials consists of crushed stone and sand and gravel and are among the most abundant natural resources and a major basic raw material used by construction, agriculture, and industries employing complex chemical and metallurgical processes. They are generally referred to as aggregates. Despite the low value of the basic products, natural aggregates are a major contributor to and an indicator of the economic wellbeing of the Nation.

16. They have a wide range of uses. These include roads, bridges, dams, airports, concrete etc. More than 90 percent of asphalt pavements and 80 percent of concrete are aggregates. Paint, paper, plastics, and glass also require sand, gravel, or crushed stone as a constituent.

17. Currently more than 80% of mining activities in Nigeria relates to the production of aggregates for infrastructure.

Mining Infrastructure

18. Mineral exploration and the search for new deposits are critical to the development of mining industry. Exploration is a major part of the industry and without it, mineral development would be impossible. Minerals occur in far flung places usually far from urban centres and developments. The building of mines that follow search and exploration of minerals require the development of supportive infrastructure: roads, railways, water transport, power etc to these places.

19. Mining specific infrastructure was developed in the past when mining was active. For example, the first power company in Nigeria was a private company (the Nigerian Electricity Supply Company (NESCO)) established to give electricity to the tin mines in Jos. At the same period there was the extension of the railway line to pass through Enugu to move coal to the ports for export. Such initiatives were stopped with the decline of the mining industry.

20. NESCO was established in 1928 and generated electricity from Kura Falls in Plateau State. The company developed other power stations in addition to the first one at Kura Falls. NESCO later extended its services to Bukuru, Jos townships and Kafanchan in Kaduna State. It ran as an independent company until the law establishing the Nigerian Electric Power Authority as a monopoly for the distribution of power was promulgated in 1972. The company was noted for its efficiency as Jos and its environs enjoyed uninterrupted power supply.

Minerals and Life

a) Minerals and Human Health

21. Geological factors play key roles in a range of issues that impact the health and well-being of humans, animals and plants. With respect o humans, the emerging interdisciplinary field

of "medical geology" respond appropriately to the wide variety of the interaction of geological environment with man. It includes nut not limited to the following:

- Geological processes and health,
- Veterinary or animal health and geology.
- Health aspects of elements in ground water
- Chronic diseases (e.g. cardiovascular disease, diabetes etc.)
- Natural environment deficiency / toxicity problems
- Trace and Essential Elements

22. All living organisms require inorganic elements, or minerals, for their life processes. An element is defined essential when it is required to support adequate growth, reproduction, and health when all other nutrients are optimal.

23. Minerals are classified in a number of ways. Often minerals that are needed in relatively large amounts are referred to as macrominerals whereas minerals that are needed in very small amounts are denoted microminerals or trace elements. Seven minerals are macrominerals and twenty –two can be referred to as trace elements (McDowell, 2003).

Table 1: Elements and Recommended Daily Adult Allowances (RDA)

Table 1 Elements and Recommended Daily Adult Allowances (RD

Element	RDA
Boron	(1.7-7.0 mg)*
Bromine	0.3-7.0 mg
Calcium	800-1300mg
Cesium	0.1-17.5 µg
Chromium	130 µg
Cobalt	15-32 µg
Copper	1-2mg
Fluoride	1.5-4.0mg
Iodine	70-150 µg
Iron	10-18 µg
Lithium	730 µg
Magnesium	3.5mg
Manganese	3.5mg
Molybdenum	160 µg
Nickel	(35-700 µg)
Phosphorus	800-1300 µg
Potassium	3500mg
Selenium	70 µg
Silicon	(21-46ug)
Tin	0.13-12.69 µg
Vanadium	(12.4-30.0 µg)
Zinc	8-15mg

*Values in brackets are for non-essential elements that are without accepted biologic function but detected in body tissues. From C Skinner (2007).

Special clinical conditions: Ca – osteoporosis, Fe – iron deficiency anemia, I – iodine deficiency (goiter) Magnesium – 'hard water '– cardiovascular disease, (Selenium – cardiovascular disease?) Eating Clay - Geophagy

24. The habit of eating soil and the physiological effects of its ingestion can be considered as the use of chemical elements in the clay to provide appropriate relief a particular need. Geophagy is defined as the deliberate and regular consumption of earthy materials such as soils, clays, and mineral substances by humans and animals. Geophagy is practised in several parts of south eastern Nigeria

Lead Poisoning In Zamfara State

25. The unfortunate incident of lead poisoning affecting mostly children that occurred with artisanal mining activities in Anka and Bukkuyum Local Government areas of Zamfara State.

26. Gold commonly associates with Lead (Pb), Antimony (Sb), Arsenic (As) Bismuth (Bi) Mercury (Hg). Milling the ore reduces the host material to dust. While milling, the lead bearing dust is inhaled.

27. The pulverized material is also panned in the stream for gold. During panning the stream is again polluted with toxic elements from the powdered rock.

28. At times, the panning for the gold from the pulverized material is done in pools of water created within the villages. This leads to the contamination of ground water and soils around the villages. Waste material dumped carelessly in the village eventually gets blown into water wells.

Figure1. Hand milling of ore in a mortal that could be used for milling food.

Figure 2. Dust and scattering of polluted ore in a village

b) Minerals and Plant life

29. The soil is the primary source of trace elements for plants, animals and humans. The trace element content of a soil depends initially on the parent material from which it was formed but subsequent leaching and nutrient cycling through plants and animal excreta creates both depletion and enrichment often in specific soil horizons.

30. Agrogeology is the application of geology to agricultural needs. It is the study of geological materials and processes that contribute to the improvement and maintenance of agro-ecosystems.

31. The use of rocks and minerals as low-cost, locally available geological nutrient resources for agricultural development is not new. It has been tested over centuries. Agricultural research with finely ground and chemically unprocessed rocks and minerals, based on the concept of 'bread from stones,' started in the 19th century by Missoux (1853/54), Hensel (1890, 1894) and others.

32. Since rocks are made up of minerals, the primary interest is in the minerals which make up rocks. Therefore the real interest is in agrominerals.
These are naturally occurring geological resources for the production of fertilizers and soil amendments.

33. This multi-disciplinary approach combines the knowledge of several professionals viz. geologist, soils scientists, process engineers and farmers.

34. Soil scientists define the soil limitations and needs, geologists find, delineate and characterize the geological raw materials that address those needs and process engineers contribute by concentrating the agrominerals and transforming them into more plant available forms. Processing technology is to be kept at an appropriate level to reflect the size, grade, location and end use of the raw material.

35. Rocks and minerals are used in crop production for:
- improving soil fertility,
- correcting the pH of soil,
- conserving nutrients and water.

35. The best known agrominerals are:
- saltpeter, the only naturally occurring nitrate mineral that occurs in sizable deposits,
- phosphate rocks (PRs) with apatite as the principle phosphate mineral,
- guano minerals, complex P- and N-bearing compounds,
- potash, mainly sylvite (KC1), and complex K-bearing salts,

- K-silicates, such as K-micas, glauconites, and K-bearing volcanic rocks and K-zeolites,
- sulphur, sulphides (e.g. pyrite) and sulphates (e.g. gypsum),
- calcium and magnesium carbonates,
- various silicate minerals and rocks used to conserve nutrients (e.g.zeolite) or used to conserve soil
- moisture (e.g. scoria and pumice).

36. Studies on Nigerian agromineral resources have shown the potential of developing the known agrominerals and finding additional mineral resources for use in agriculture, horticulture, forestry and agroforestry.

37. The agrominerals found and tested suitable for direct application in Nigeria are:
- Feldspar
- Marble
- Gypsum
- Phosphatic Nodules
- Phosphatic Limestone
- Gypsum
- Peat/Lignite

Solid Minerals in Nigeria's Historical Economy and Development

38. Solid Minerals has played a long and important role in the in the industrial history of Nigeria. Solid minerals were very important prior to 1970. Before this period there was boom in the exploration, exploitation and exportation of solid minerals such as coal, tin, columbite and wolframite.

39. Organised mining in Nigeria began to crystallise between 1902 and 1923 following the commissioning in 1903 and 1904 of the Mineral Surveys of the southern and northern protectorates. Tin deposits had been located in Jos plateau and organised mining activities were initiated by the Royal Niger Company in 1905.

40. Apart from tin and other associated minerals, such as columbite, and tantalite, mining for gold began in 1914 in areas now known as Niger and Kogi states. Exploration for coal dates back to 1906 but production did not commence until 1916 in the area now known as Enugu state. By 1919, the Geological Survey of Nigeria was established as a department of government to take over and continue the work of the previously established survey teams.

41. The Minerals ordinance of 1946 and the Coal ordinance No. 29 of 1950 provided the legal basis for the development of solid minerals in Nigeria. Specifically the work of the Mineral Surveys of Nigeria (and later the Geological Survey of Nigeria) led directly to the establishment

of the tin mines in the Jos plateau and the coal Mines at Enugu. It also led to the development of mineral based industries and plants such as the thermal generating plant at Oji River Station and Ijora Lagos, steam powered transportation of the Railways and Inland Water Ways, the cement plants at Nkalagu, Ewekoro, and Calabar. It contributed greatly to foreign exchange earnings.

42. The economic focus however shifted during the oil boom of the 1970's. The nation evolved an economy (monolithic) based solely on revenues from oil. Little attention was given to other sectors such as agriculture and solid minerals.

Geology of Nigeria

43. The Geology of Nigeria is composed of four main groups known as the Basement Complex, the Younger Granites, the Sedimentary series and the Tertiary-Recent Volcanic rocks. The

Basement Complex

44. The Basement Complex of Nigeria occupies the central part of the Pan- African mobile belt, which lies between the West African and Congo cratons. It occupies about half the surface area of Nigeria. It is composed of three major rock packages:

i. The migmatite-gnesis complex.
ii. The schist belts composed of metasedimentary and metavolcanic rocks.

iii. The pan-African Granitoids comprising the Older Granites and associated charnockitic rocks

The Younger Granites

45. The Younger Granites are distinct from the Older Granites (Pan-African granitoids), and are high-level anorogenic volcanic and hypayssal rocks emplaced within the Precambrian basement complex. They are characterized by arcuate to circular intrusions and represent one of the classical occurrences of ring complexes in the world. They are form the southern extension of similar ring complexes in Air, Niger Republic. The Nigerian occurrences range in age from 313 to 141 million years.

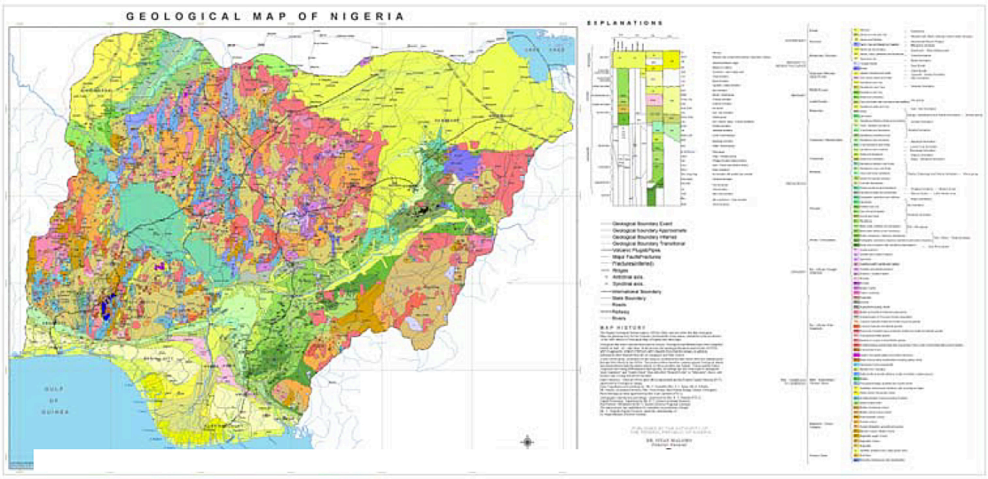

Figure 3 Geological map of Nigeria

The Sedimentary Series

46. The sedimentary rocks of Nigeria were deposited in seven basins surrounding the crystalline rocks. They outcrop over about half the surface of Nigeria. Five of them, the Niger Delta Bida, Benue and Anambra basins appear to have initiated in the Cretaceous and are related to the opening of the Gulf of the Guinea. The remaining two, the Sokoto and Chad basins are part of the Taodeni and lllumedden basins respectively, which outside Nigeria have histories dating back to the Palaeozoic.

The Tertiary - Recent Volcanic Rocks

47. Volcanic activity has taken place intermittently from tertiary to recent times. The most extensive outcrops are in the Biu and Longuda plateaux of north-eastern Nigeria and on the Jos Plateau and in the Benue Trough. The basalt ranges from 22 million years to 7 million years in age.

Nigeria's Solid Mineral Endowment

48. Nigeria is richly endowed with various mineral types that manifest inmultiple occurrences all over the country coupled with the presence of several vast mineral deposits of world class.

49. The solid mineral resources of the country may be categorised into three broad groups:

i) Metallic and Precious Minerals

Examples of these include cassiterite (tin ore) lead and zinc, iron ore, manganese, tantalite/columbite and gemstones.

ii) Energy Minerals

Examples of these include coal, lignite, bitumen (tar sands) and radio-active minerals.

iii) Industrial Minerals

Examples include barytes, gypsum, clays, limestone, marble, phosphate, silica sands and dimension stones.

50. Every state of Nigeria including the Federal Capital Territory has the presence of solid minerals. However many of these resources are still untapped.

More than 40 types of solid minerals have been identified in over 500 locations in the country.

51. The major minerals and the States of occurrence are shown below:

Gold: Cross River, Edo, FCT, Kaduna, Kano, Kebbi, Kogi, Kwara, Niger, Osun, Zamfara

Iron Ore:Edo, Enugu, Kaduna, Kogi, Taraba, Zamfara

Lead/Zinc: Kano, Ebonyi, Bauchi, FTC, Plateau, Nasarara, Taraba, Zamfara

Coal: Benue, Ebonyi, Enugu, Gombe, Kogi, Nasarawa, Plateau

Lignite:Abia, Anambra, Delta, Edo,Gombe, Imo

Bitumen:Edo, Enugu, Lagos, Ondo, Ogun

Limestone: Abia, Adamawa, Akwa Ibom, Benue, Cross River, Borno, Ebonyi,
Enugu, GombeKebbi, Ogun, Osun, Taraba, Yobe

Marble: Edo, FCT, Katsina, Kogi, Kawar, Niger, Oyo, Plateau, Zamfara

Barytes:Benue, Cross river, Nasarawa, Taraba, Adamawa

Cassiterite : Adamawa, bauchi, Ekiti, FCT, Jigawa, Kaduna, Kano, Katsina,
Kogi, Kwara, Ondo, Plateau

Manganese: Cross River, Kaduna, Kebbi

Tantalite/Colunmbite: FTC, Kaduna, Kwara, Kogi, Nasarawa, Niger, Osun, Oyo, Taraba, Zamfara

Columbite: Bauchi, Ekiti, Jigawa, Kaduna, Kano, Kogi, Kwara, Nasarawa,
Osun, Plateau, Taraba, Zamfara

Gypsum: Anambra, Bauchi, Bayelsa, Edo, Enugu, gombe, Ogun, Sokoto, Taraba, Yobe

Phosphate: Abia, Edo, Ogun, Sokoto

Silica Sand: Akwa Ibom, Anambra, Bayelsa, Delta, Edo, Enugu, Jigawa, Kano, Lagos, Ondo, Ogun, Rivers

Dimension Stones:Most of the States of the Federation and the FCT

52. Out of the list showing above, the following are the world class minerals are found in Nigeria. These minerals by definition are capable of attracting large foreign direct investment and can make important contribution to the GDP. They are:

- Bitumen – 27 billion barrels of oil equivalent
- Coal – 1.5 billion metric tonnes inferred
- Gold – 10 locations > 50,000 ounces inferred resources
- Barytes – 13 million metric tonnes inferred resources
- Iron Ore – 100million metric tonnes inferred resources

Reforms in the Mineral Development Sector in Nigeria

53. The Federal Government that has the singular responsibility of developing minerals has been mindful of the poor contribution to the economy to the mining sector for sometime.

54. A dedicated Ministry of Solid Minerals was established in 1995. Despite the establishment no major change was recorded in the contribution to national economy. The annual contribution to the GDP between 1999- 2006 was below.

55. The identified factors that hindered the development of the sector include:
i. Opaque licensing procedures leading to speculative holding of mineral titles
ii. Low revenue generating capability
iii. Prevalence of illegal and artisanal miners
iv. Conflict between Federal/State governments over ownership of mineral rights
v. Existence of too much discretion granted by the Minerals and Mining Act 1999, which was not private sector friendly.

56. To improve on the situation, and attract large direct foreign investments, root and branch sector reforms were carried out during 2005-2008. The reforms include:
i. Development of a National Policy with clear direction of future activity in the sector.
ii. Review of the 1999 Minerals and Mining Act to provide incentives for private sector participation. This is to the promulgation of a new Minerals and Mining Act.
iii. Restructuring of the Ministry for enhanced performance and better administration/regulation of the sector.
iv. Privatisation/Deregulation of some of the parastatals.
v. Curbing of illegal mining.
vi. Strengthening geological data generation.
vii.Promotion and marketing of investment opportunities.

57. The elements of the reforms are similar to the broad reform categories adopted by countries that have experienced resurgence in mining activity in the 1990's. These include countries as Tanzania, Mali, Bolivia, Peru, Madagascar, Mongolia and Burkina Faso.

58. These reforms are now been stabilised by the current Minister of Mines and Steel Development who is our Special Guest of Honour today. We will demonstrate later in the lecture some of the impact of these reforms in the second part of this lecture. This is built on Item vi of the list above i.e. the strengthening of geological data generation and the infusion of science.

PART 2: MINERAL RESOURCES DEVELOPMENT IN NIGERIA

Mineral Exploration in Nigeria: Dowsing, Lottery, Serendipity or Science Dowsing

59. Dowsing is defined as a type of divination employed in attempts to locate ground water, buried metals or ores, gemstones, oil, gravesites and many other objects without the use of scientific apparatus. Dowsing is as strictly defined the claimed ability to discover underground

sources of water or metals by means of a "dowsing rod." Another term used is "divining." However, this terminology and its scope have been expanded and are now used with a far greater range of meanings.

Figure 4 Dowsing rods

60. Dowsers use a Y- or L-shaped twig or rod claim a response of the rod to buried objects.

61. Dowsing has been used for a long time in Europe and America (since the Renaissance of magic in Germany) and in fact remains popular among believers there is no accepted scientific rationale behind the concept and no scientific evidence that it is effective.

62. Surprisingly dowsing continued to be used to date and in societies that should know better. A search on the internet provides the following list of work and reports in the last fifty or so odd years. Some of them in last year!

- In the late 1960s during the Vietnam War, some United States Marines used dowsing to attempt to locate weapons and tunnels
- An extensive book on the history of dowsing was published by Christopher Bird in 1979 under the title of The Divining Hand.
- A 1986 article in Nature included dowsing in a list of "effects which until recently were claimed to be paranormal but which can now be explained from within orthodox science.

63. A number of devices resembling "high tech" dowsing rods have been marketed for modern police and military use: none have been shown to be effective.

- The more notable of this class of device are ADE 651, Sniffex, and the GT200.
- Global Technical GT200 (manufactured by Global Technical Ltd) is a dowsing type ex-

plosive detector which contains no scientific mechanism.

- Sandia National Laboratories tested the MOLE Programmable System manufactured by Global Technical Ltd. of Kent, UK and found it ineffective.[28]
- A US government study advised against buying "bogus explosive detection equipment".
- The ADE 651 is a device produced by ATSC (UK) and widely used by Iraqi police to detect explosives. Many have denied its effectiveness and contended that the ADE 651 failed to prevent many bombings in Iraq.
- On 22 January 2010, the director of ATSC, Jim McCormick was arrested on suspicion of fraud by misrepresentation. Earlier, the British Government had announced a ban on the export of the ADE-651
- SNIFFEX was the subject of a report by the United States Navy Explosive Ordnance Disposal that concluded "The handheld SNIFFEX explosives detector does not work."

Lottery

64. Lottery by definition is a chance event and the process that produces the outcome is in the realm of low probability. It is a mere 'throwing of the dice'.

Although the outcome is determined by chances it important that some consideration is given to taking part in the process. The person playing the lottery believes that this might lead to simple ways of removing the odds. In many cases they do not. It is the same for mineral exploration.

65. Current expansion in mineral exploration is no more than a lottery as it is speculative. Mining companies from Nigeria and abroad staked claims in tenement adjacent or near existing occurrences or mines in the hope that the occurrence in point A, would probably extend to another point B.

66. The informed mining companies are engaged in enlightened speculation. In this case investors engage geologist who with limited data or knowledge extrapolate the occurrences based on proximity or similarity existing resource.

67. A case in point is the search for Gold in Osun and Zamfara States where most of the areas around historical mines have been covered by speculative licenses, many of which have found little or nothing.

68. Many of the speculative nature and the odds in mineral exploration can certainly be reduced by application of rigorous scientific principles in the search for the minerals. The data, information and knowledge for this to happen are now available and this will be demonstrated later in this lecture.

The Barefoot Doctors in Mineral Development

69. The purveyors of dowsers and lotteries are what I have called elsewhere the barefoot experts (Malomo 2004). The terminology refers to amateur, novices, charlatans and a motley crew of uniformed people who make pronouncement on mineral resources and even proffer advice and provide services on mineral exploration and development.

70. They invariably are involved in mining activities, most of which are illegal and sometimes dangerous. The positive origin of the word barefoot (e.g. the barefoot doctors of China) usually would not apply to the one in mineral exploration or mining.

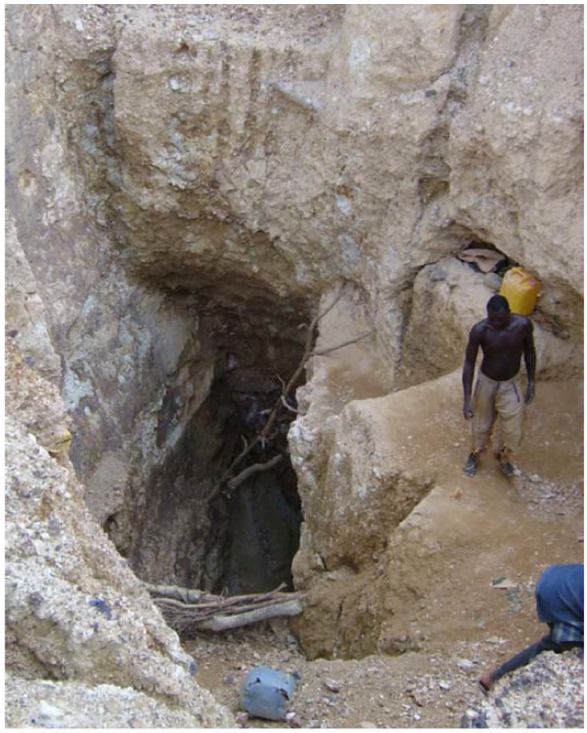

Figure 5. Illegal Mining of Barytes

Figure 6. Environmental degradation due to the mining of barytes

Serendipity

71. Serendipity is the accidental or consequential event or is unplanned or unexpected result of a planned action. It is a fortuitous discovery, especially while looking for something entirely different.

72. Its root of the word comes from comes from Serendip an old Persian name for Sri Lanka; however its usage in English is from an English writer Horace Walpole, who wrote a fairy tale called The Three Princes of Serendip.

73. It is the surprise that shows up when a scientist is conducting a process and an unexpected substance or reaction occurs. According to the Oxford English Dictionary, the precise definition is "The faculty of making happy and unexpected discoveries by accident."

74. The simplest way to describe "serendipity" is to call it a happy accident. In other words, a serendipitous event is an extremely pleasant and unexpected surprise.

75. An example of a serendipitous discovery is that of development of penicillin when Alexander Fleming discovered that the staphylococci bacteria culture he had neglected to clean up before going on vacation would not grow around mould on a plate.

76. Other events like the discovery of electricity and making of raisins or peanut butter are serendipitous, simply because the personnel involved sought to discover something other than what they actually discovered.

77. However Serendipity can only be achieved and indeed produce a useful outcome through preparation. There is no substitute for a good education and good grounding in science. It is captured in the words of Louis Pasteur (the French scientists) who said, that in the field of observation, chance favours only the prepared mind.

78. The ability to spot the significance of inconsequential clues is a skill that separates the erudite from the novice; and it is the outcome of such observations that brings value for the advancement of science and thus presents a platform for us to understand what we didn't understand before.

79. Serendipity is a lot more than finding a pot of gold in a muddy puddle at the end of a rainbow. It is therefore well beyond the realm of dowsing and lottery. Serendipity would apply in the search for Lead (mineral galena) which usually occurs with Zinc (mineral sphalerite) but throws up substantial amounts of Silver (native or Argentite) which usually has more economic value than the original objects of interest.

Science

80. Science is from the Latin scientia, meaning "knowledge". Aristotle used the words to mean a corpus or body of reliable knowledge that can be logically or rationally explained. The origin of science is linked to philosophy and only fairly recently has the there been a distinction.

81. It is now accepted as a collection of ideas; data, information and knowledge that has an underlying link that are testable and predictable. The value of science and scientific methodology lies in predictability and repeatability.

82. There are several approaches to the fundamental understanding of scientific enquiry but I would like to quote Richard Feyman who said, the principle of science, by definition, is that "the test of all knowledge is experiment. And that there is "an expanding frontier of ignorance"

83. This lecture is not about a discourse on science, scientific enquiry or the scientific method. I have brought the matter of science to show distinction between what had gone on in the mineral industry in Nigeria until recent times an what is now been done about it in the last few years particularly in the

Nigerian Geological Survey Agency which I head.

84. A famous quote that I use (I am not sure of the origin though) while talking to students is to recognise the "difference between knowing something and knowing the name of something". The barefoot experts and practitioners of pseudo-science in mineral exploration just know the name of something!

Science and Mapping at the Nigerian Geological Survey Agency

85. The NGSA is the primary Agency for Geoscience of the Federal Government of Nigeria. It is in the review of the progress achieved by the Agency, in the lasts six years, that one can see the spectacular, but unheralded progress, that has been achieved by the country in acquiring new scientific data and tools for the opening up the information on the geology and mineral resources of the country.

Mapping History

86. Mapping for mineral investigation in Nigeria commenced in 1903 and the Geological Survey of Nigeria was formerly established in 1919. At the establishment the mapping was responsible for the mineral finds such as the Jos Plateau (tin), Enugu (coal) Ewekoro (limestone). However the mapping was directed only at areas where potential benefits have been identified leaving large gaps in areas that could be possibly mineralised but not known at the time.

87. To fill the large gap areas, systematic geological mapping for nationwide coverage of the country was carried out 1952- 1975. Most of the results were not published following decline

of interest in solid minerals developments after the discovery of oil. The outputs of the efforts (preliminary reports and maps) were abandoned in shelves and cupboards of the former Geological Survey Department (GSD).

88. The inactiveness of the GSD under various ministries (Mines and Power, Mines Power and Steel, Petroleum and Minerals, Solid Minerals) led to the establishment of an autonomous Agency, the Nigerian Geological Survey, for the accelerated mapping, generation and dissemination of geoscience data and information.

Current Mapping and Outputs

89. The Nigerian Geological Agency mindful of the tremendous challenge and gaps that it has to fill as a consequence of the long years of decline has correctly reemphasised the use of broad mapping tools for mineral investigation in the country.

90. This is of course as it should be, as geological surveys all over the world normally carry out broad investigations, to ascertain the resources , document, archive and disseminate these information to users. The users namely investors, academic and those with engaging curiosity who can them take on the data and information for a deeper analysis and enquiry.

91. It is not that Geological Surveys should not have the capacity (human, equipments and facilities) to carry out further and deeper mineral investigations. It should, but the argument is that it should only do so when called upon to do so for a specified and important reason. Notable examples include national decision making or at chargeable cost to the private sector as in a consultancy.

92. Three types of surveys are currently employed. These are:
i. Regional Geological Mapping
ii. Airborne Geophysical Surveys
iii. Regional Geochemical Mapping

Regional Geological Mapping

93. It is now widely accepted that regional geological mapping and the outputs of mapping viz. maps, mineral databases, petrographic studies, geochemical analyses are the bedrock of the information that mining companies require to take decisions whether to invest in a country or not.

94. Regional Geological mapping provides information on the rocks on every part of the country i.e. beneath our feet (whether mineralised or not). Such information is useful for the identification and development of mineral resources, land use planning, agricultural and infrastructural development.

95. Geological mapping is carried out at different (and fit for purpose) scales. The scale of a map to be used depends on the purpose for which it is required. For instance the geological mapping required for foundation studies for a new highway route location between States would require maps at a scale of

1:250,000 while foundations studies for urban road would require maps at

1:100,000 or greater. Similarly the mapping required for a broad knowledge of mineral occurrence in the country would require maps at scale of 1: 250,000

96. A more appropriate scale of mapping required for mineral investment and infrastructure development is at scale of 1:100,000. In producing maps of the country during the early years of geological mapping, emphasis was placed on known mineralised areas, such as the tin fields of Jos plateau and coalfields of Enugu, the mapping of the rest of the country which could equally be mineralized was not give attention.

97. The field work for systematic geological mapping at 1:100,000 scale commenced in the 1950's and was 95% completed by 1990. However less than 6.5% (22 out of possible 337 maps) of the initial work was carried to fruition, in the production of geological maps and reports. The results of the field exercise were limited to notes and field maps, kept in shelves and cupboards, most of which are now either lost or obsolete.

98. The NGSA in 2004 began to update the work where possible and have taken the field mapping to fruition in producing and publishing maps on the appropriate scale. It has now produced additional 17 maps.

99. Having regard to the need to upscale the geological mapping of the country for mineral investment, the Agency has also begun fresh systematic mapping of all unmapped areas in all the geopolitical zones of the country.

100. Currently out of a possible 337 maps at the scale of 1:100,000 only 48 have been produced to date (since 1919 – 22 maps before the establishment of the NGSA and 26 maps since the establishment).

100. NGSA started the journey by publishing small scale maps,

Published maps to date are:

- National Maps – 3, Maps of all Geopolitical zones – 6, Maps of all the States of the Federation and the FCT – 37
- Localised (Sheet) Maps on 1:100,000 – 26
- Commodity maps of the Strategic Minerals – 7, Combination

Commodity Maps – More than 2million is possible depending on the request

- Current Projects
- Map publication – 22 maps in progress

- Detailed Geological Mapping on a scale of 1: 50,000 to be published on 1:100,000 – (36 projects to produce 9 maps)

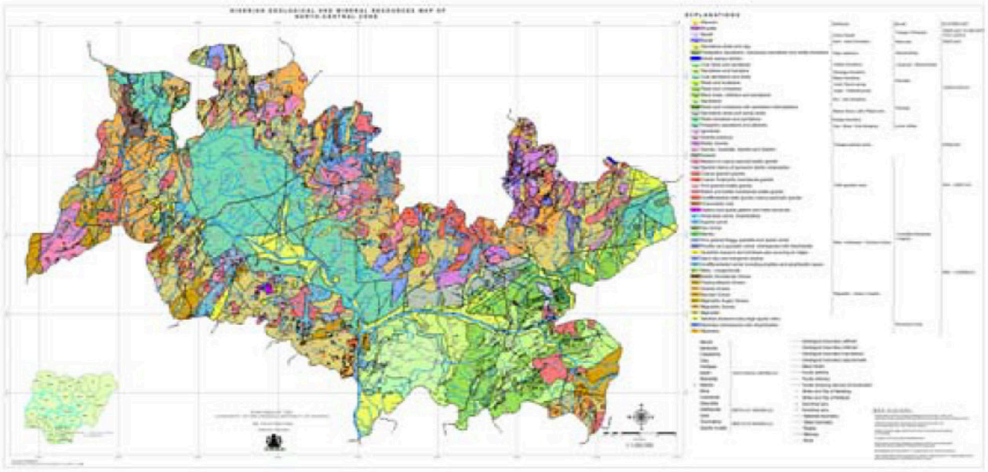

Figure 7 Regional Map (1:500,000) of North-Central Nigeria

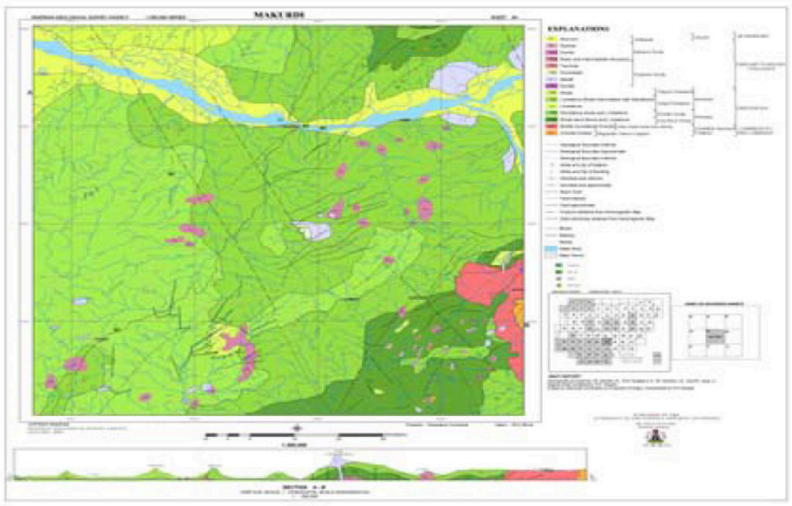

Figure 8. 1: 250,000 Geological Map of Makurdi sheet

Airborne Geophysical Surveys

101. Airborne Geophysical Surveys is a rapid and effective way of unravelling areas of possible mineralisation and is currently being carried out by more than forty countries in the world. The aims of the surveys are:

a) To produce a fast coverage of vast areas;
b) To produce a cheaper and faster rate of coverage
c) To overcome problems of rugged and inaccessible terrains.

102. We have been using a variety of geophysical techniques at the NGSA. The most common are magnetic, radiometric and gravity.

103. Gravity and magnetic exploration are potential fields exploration. They are employed to provide non-intrusive methods of identifying the nature of earth beneath the Earth's surface through the sensing of different physical properties of rocks (density and magnetization, respectively). Gravity and magnetic exploration can help locate faults, mineral or petroleum resources, and ground-water reservoirs.

104. Aeromagnetic anomaly maps show variations in the Earth's magnetic field that are caused mainly by magnetic minerals in crustal rocks. These anomalies vary with amount and type of magnetic material and the geometry and depth of the magnetic body. Igneous and metamorphic rocks frequently are magnetic enough to cause anomalies, whereas sedimentary rocks commonly are nonmagnetic.

105. The differential between these types of rocks can also be employed in identifying the nature of the rocks. This enhances the usefulness of aeromagnetic surveys as mapping tools. Aeromagnetic anomaly maps are important tools for mapping superficial and buried rocks, for determining geologic structure, and for discovering some types of mineral deposits.

106. Regional geological features may become evident after individual aeromagnetic surveys are compiled and plotted at the same scale in a consistent way.

Radiometric Surveys

107. Radiometrics is a measure of the natural radiation in the earth's surface, which can tell us about the distribution of certain soils and rocks. Geologists and geophysicists routinely use it as a geological mapping tool to ascertain rock types and changes in rock formations.

108. Radiometric surveys involve the measurement of gamma radiation resulting from natural radioactive sources. Instruments are available to measure either total count or provide spectral information on individual elements such as uranium, thorium and potassium in order

to identify specific sources of radiation.

109. Radiometric measurements are primarily used in mineral exploration but can also be applied to the detection of faults, location of caves and for mapping contamination.

110. From airborne surveys, using the distinctive gamma ray spectra from the three radioactive elements, the concentrations of potassium, uranium and thorium have been mapped over 100% of the required areas for information in Nigeria.

Nigeria's Airborne Geophysical Surveys Programme

112. The Federal Government of Nigeria has now completed the acquisition of airborne magnetic data for the entire country. This was recently completed with the last tranche of the project on the Niger Delta. In addition radiometric data acquisition for all the required areas (the county minus the Niger Delta on account of the wetness was acquired. Gravity data was acquired for the Niger Delta only.

113. This represents 2.5 million line kilometres for the magnetic, 1.94 million line kilometres for the radiometrics and 4.5 million line kilometres for the gravity data. All the data sets were acquired at 500 metre spacing at a flight height of 80metres. The ambitious data set represent the only country in Africa with such total coverage to date.

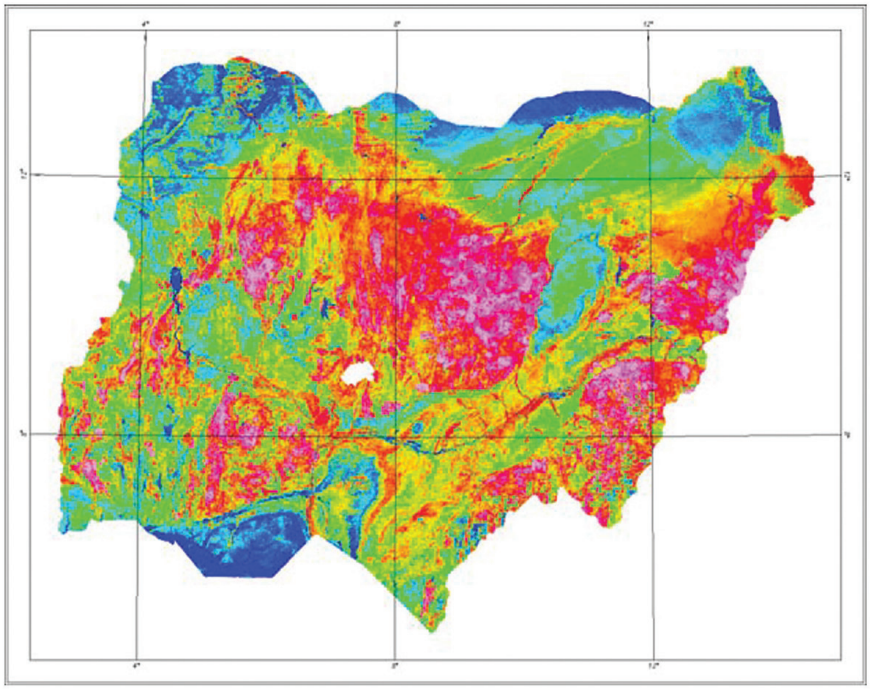

Figure 9 Total Magnetic Intensity map of Nigeria (minus the Niger Delta)

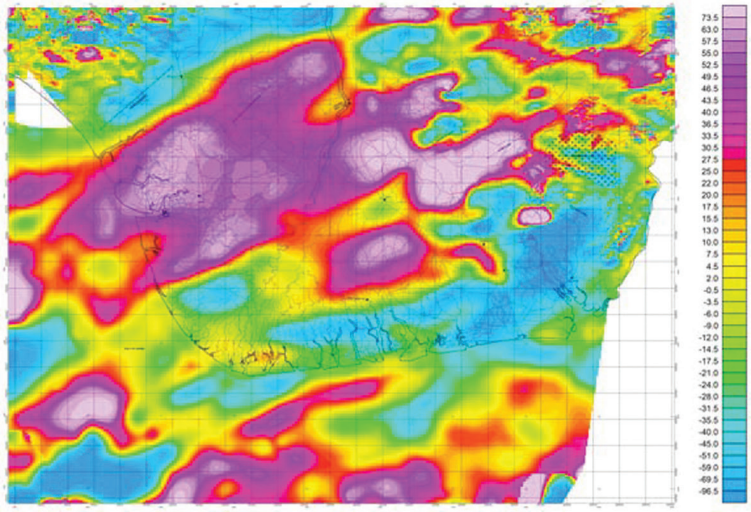

Figure 10 Total Magnetic Intensity map of the Niger Delta

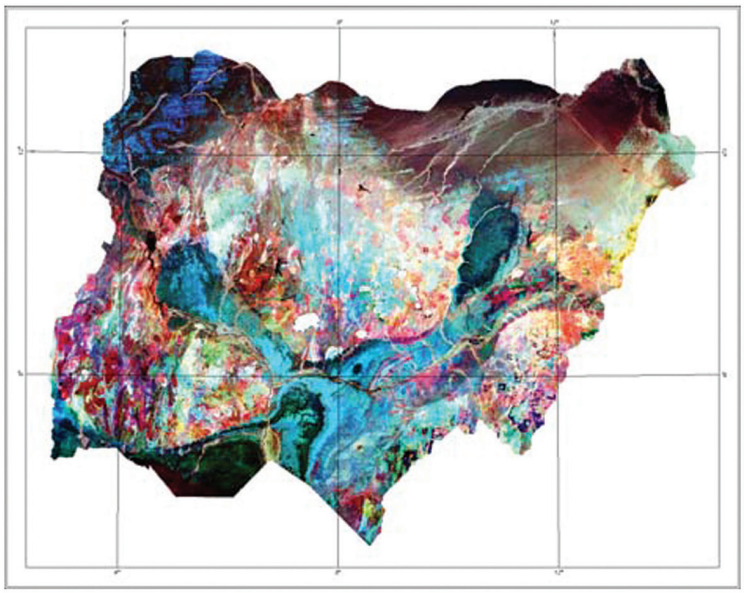

Figure 11 Ternary Radiometric Map of Nigeria (minus the Niger Delta)

Regional Geochemical Mapping

114. This is the analysis of soil, sediments and water (sometimes plants) on a regional basis to produce a body of geochemical data for the country. The sampling and the analyses are carried out using a consistent set of methods.

These dataset produced will generate complete, national-scale geochemical coverage of the country. It enables the production of geochemical maps and provides broad estimates of baseline (or background) geochemical values.

115. The purpose of regional geochemical mapping is to provide information on prospective areas for mineral exploration and where possible information on the relationship between health and trace element deficiencies and toxicities in the environment.

116. Regional and national-scale geochemical surveys have been used for many decades to locate areas of the Earth's crust where mineralisation processes have occurred. Data generated for geochemical exploration purposes can also be used to establish geochemical baselines for use in environmental

Figure 11 Ternary Radiometric Map of Nigeria (minus the Niger Delta) studies, to resolve controversies arising from questionable correlation of geologic units, and for many other purposes.

117. The outputs fro geochemical mapping surveys are usually multi-element atlases showing the distribution of elements on a regional scale. Several maps are usually produced. More than 50 different maps can be produced, with each depicting a particular distribution of element.

118. The Nigerian Geochemical Mapping Project consists of four components. An initial component funded by the Federal Government carried out by the NGSA Staff, a second component which is collaboration between the British Geological Survey (BGS) and the Nigerian Geological Survey Agency (NGSA) facilitated by the Sustainable Management of Mineral Resources Unit of the Ministry of Mines and Steel Development. A third component carried out by NGSA staff with some supervision by the BGS and a final component to be done by NGSA staff without any supervision.

119. The purpose of the project is to provide baseline geoscientific information for mineral exploration and environmental management through a study of the distribution of important metallic elements on the Nigerian land surface. The Global Reference Network is made up of 5000 cells out of which 44 are contained wholly or partly in Nigeria. The project has completed the first two components and begun (November 2010) the third component.

120. The collaboratory effort of the second component obtained stream sediment samples from two of these cells, analysed the samples and produced geochemical maps. 80 Nigerians and about 20 foreign earth scientists were involved in the collection, analysis and interpretation of the samples.

121. A total of 1656 stream sediment samples were analysed comprising 284 and 1307 stream sediment samples from two cells in the South-western and Minna areas respectively, and 65 standard control samples. The samples were analysed in the BGS Keyworth laboratories as well as at the Acme Laboratories in Canada. The concentrations of a total of 57 elements were obtained using ICP-MS. Key and Johnson (2010).

Figure 12. Global Reference Network (GRN) Index Map for Nigeria. The darker cells are the areas mapped to date

Total number of cells for Nigeria: 44. Completed: 6 Cells, On-going: 2

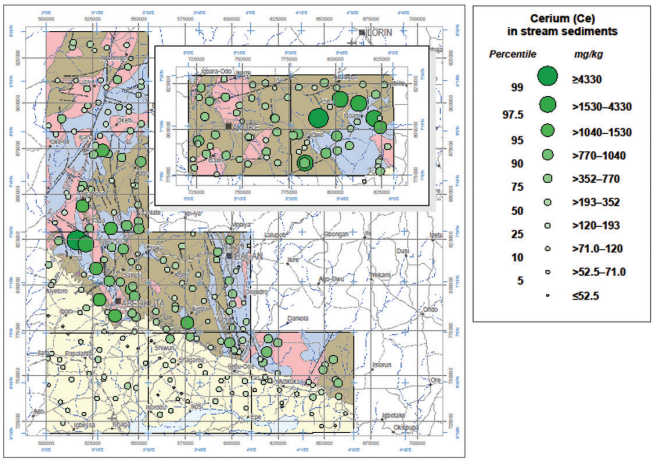

Figure 13. Cerium (Ce) distribution in the South-western Master Cell

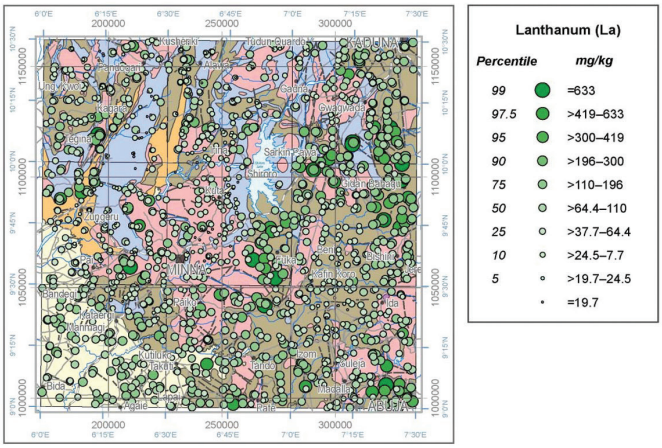

Figure 14. Lanthanum (La) distribution in the Minna Master Cell.

The Outcome of the Minerals Development Reforms

122. There are already, green shoots of recovery in the effort by the government. One barometer of change is the number of enquiries (including investors) received in the last four years. Figure shows the number of enquiries received at the offices nationwide during 2007-2009

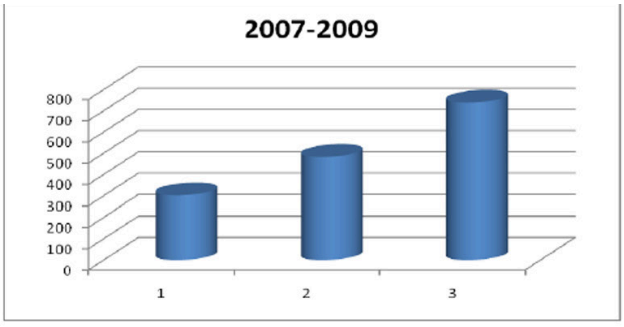

Figure 15. Nationwive NGSA Investor Enquiries 2007-2009

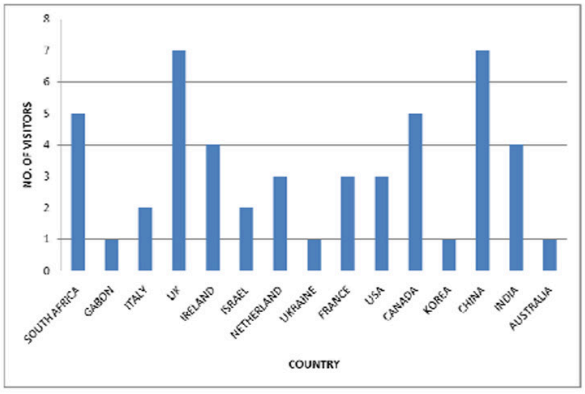

Figure 16. Summary of Foreign Investors by country to NGSA Headquarters' Customer Service Centre (2009)

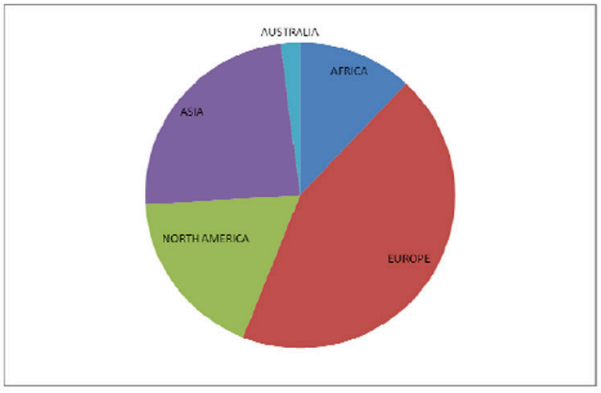

Figure 17. Distribution of Foreign investors to NGSA Headquarters' Customer

CONCLUSION

123. I have gone at great length to illustrate that geology is no longer confined to the study of rocks and minerals but for a variety of purpose beyond wining of metallic and non-metallic products for sale.

124. Outcomes of the mapping surveys have shown us that there is no replacement for logic and science in development. Record of overseas visitors at the NGSA headquarters in Abuja since May 2006; have shown a significant increase in numbers and quality of enquiries. We are now having enquiries from credible local and international investors.

125. The understanding of the nature, distribution and value of Nigeria's Mineral resources have an impact on the generation of wealth, industrial development provision of infrastructure and the sustenance of life on earth.

Mr Chairman
Special Guest of Honour
Thank you for the attention. God bless you.

References

Baker R R., Mather J G, and Kennough J H. (1983). Mahnetic bones in human sinuses. *Nature*. 301: 78-80

BBC News 23-01-2010. "'Bomb detector' maker arrested". BBC News. 2010-01-23. http://news.bbc.co.uk/2/hi/uk_news/8476381.stm. Retrieved 2010-05- 01.

BBC news 22 -01-2010, "Government statement on 'bomb detectors' ban". BBCNews.http://news.bbc.co.uk/2/hi/programmes/newsnight/8475875.stm.

CNN 17-02- 2010 "Tests show bomb scanner ineffective, Thailand says". CNN. http://www.cnn.com/2010/WORLD/asiapcf/02/16/thailand.bomb.scanner/index.html?eref=rss_topstories&utm_source=feedburner&utm_medium=feed&utm_campaign=Feed:+rss/cnn_topstories+(RSS:+Top+Stories).

Enright J T. (1995). Water dowsing: The Scheunen experiments. *Naturwissenschaften* 82: 360-369.

Hambidge K M., Casey C E. and Krebs N F. (1986). Zinc. In: Trace elements in Human and Animal Nutrition. Ed: W. Mertz. Academic Press Inc. (London) Ltd., 2,1-137. Netherlands, 644 pp.

Hines T. (2003). Pseudoscience and the Paranormal (Second ed.).

Amherst, New York: Prometheus Books. p. 420. ISBN 9781573929790.

Key R M and Johnson C C. (2010). Final report of the Nigerian geochemical mappingand technical assistance project. Nigerian Geochemical Mapping Technical Assistance Project. British Geological Survey Commissioned Report, CR/10/56. 188pp.

Malomo S (2004) Geological Surveys, Mineral Exploration and the Challenge of Barefoot Doctors University of Ibadan, Ibadan 44pp

Marks D F. (1986). "Investigating the paranormal". *Nature* 320 (6058): 119–124.

McDowell L R. (2003). Minerals in animal and human nutrition. Elsevier Science B.V., Amsterdam, ThePresti D. and Pettgrew J. *Nature* 285, 99 (1980) :10.1038/28509

Skinner C. (2007). The earth, source of heath and hazards: An introduction to medical geology. *Annual Rev. Earth Planet Sci*. 35: 177-213.