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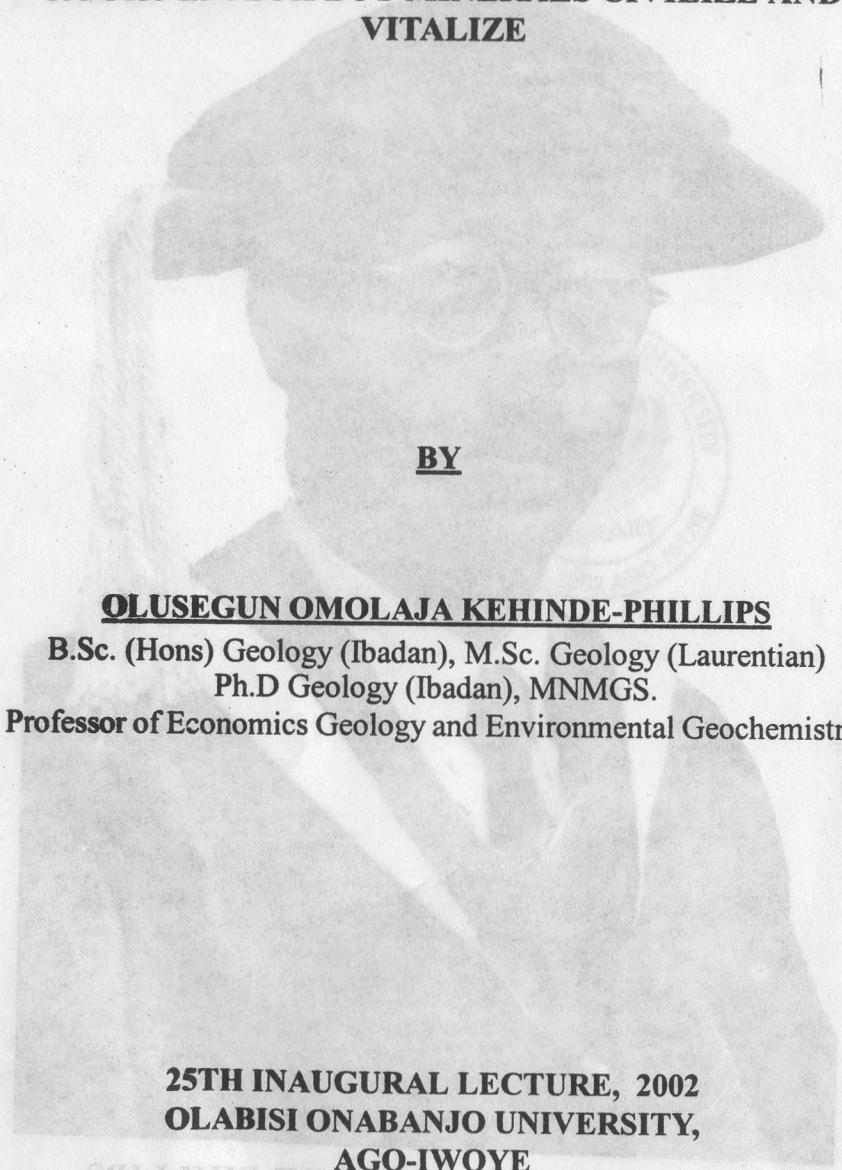
ROCKS ENRICH BUT MINERALS CIVILIZE AND VITALIZE



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25TH INAUGURAL LECTURE, 2002
OLABISI ONABANJO UNIVERSITY,
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INTRODUCTION

Mr. Vice-Chancellor, I feel highly honoured to be invited to deliver the 25th Inaugural Lecture of this great University today.

The title of my Lecture is: Rocks Enrich, But Minerals Civilize and Vitalize. Let me begin by giving a brief history of the Science of Geology and its conflict with the accepted religion of the time.

The fundamental principles of geology, which is the study of rocks and landforms were discovered in the decades 1790 – 1820. These decades have been termed the heroic age of geology. Geology developed into a Science during the Industrial Revolution, being stimulated by the prospecting for coal and mineral deposits. Its rise also coincided with the Romantic Movement, when mountains and the wild recesses of nature became suffused with a new interest. Geology as science, has profoundly altered popular conceptions of time, the Church, man and the balance of nature.

Modern geology began in style. In 1785, James Hutton, a 58-year-old naturalist and farmer, presented to the Royal Society of Edinburgh, his thoughts and I quote: "Concerning the system of the earth, its duration and stability" unquote. The paper dealt with the lands and the Seas in a succession of former worlds and the power of water to wear away rocks. It painted a scene of immeasurable antiquity, constant in change, and evidently endless. "With respect to human observations, this world has neither a beginning nor an end" he wrote. Hutton's words, as later events were to prove, struck a mortal blow to the ruling notion of secular time.

And of what importance was that? When Isaac Newton and the astronomers a century before had expanded the Universe in space, beyond any constraints other than natural law, the established and popular view of Creation suffered no harm. When Hutton and the geologists, however, expanded the created world in time, they seemed to be challenging the

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Divine word. There was a reason for this: the English-speaking peoples had for two centuries resisted the authority of their original Church, preferring to substitute the authority of the English Bible. Divine authority rested in the scriptures and to question them seemed to question Providence itself. The creation of the world, said the Bible was accomplished in six days. Hutton and the geologists were saying that even six millennia could not meet the facts. Thus the geological concept became a religious issue, and a conflict of appropriate ferocity commenced.

There were repeated controversies between geologists and the upholders of the literal truth of Genesis, in which the whole future of Christianity was held by the latter to be at stake. The geologists eventually emerged victorious. The observation of nature triumphed over the Revelation of scripture. It was established that the earth had not been created about 5,000 years ago but that it has been in existence for 4.5 billion years; that Noah's flood was merely an episode in a series of local inundations. It is important to mention this conflict between Geology and Religion so that the title of this lecture is not regarded as sacrilegious. Some people here will affirm that only God enriches, civilizes and vitalizes and not rocks. To such people I say, please hear me out before you crucify me.

ROCKS ENRICH

Rocks are aggregates of minerals. The mineral deposits and metal ores that enrich individuals or nations are hosted by rocks. Field observations disclose an association of certain ore minerals with specific rocks that is so general and widespread as to exclude coincidence. Some igneous rocks are themselves bodies of ore such as some deposits of chromite, ilmenite, corundum, diamonds and some magnetite deposits. Since these are merely igneous rocks, although of unusual composition, they indicate a direct relationship between magmas and mineral deposits. This association establishes a direct relationship between the ore minerals and rocks, indicating thereby, a magmatic source for both. For example, primary platinum deposits occur only in ultramafic rocks such as dunite or peridotite,

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diamond in Kimberlite, Nickel in Serpentinite, ilmenite in gabbro of anorthosite, Corundum in quartz-free rocks such as nepheline-syenite, tin in silicic granites and beryl in granite-pegmatite.

In addition to these mineral deposits of igneous rocks are those associated with sedimentary rocks such as Sedimentary Iron and Manganese deposits and those of metamorphic origin such as asbestos and talc. Thus rocks enrich with the minerals they host and have so enriched Nigeria that the country is endowed with many mineral resources. Nigeria's two main geological terrains of basement complex rocks and sedimentary basins are hosts to important mineralizations as shown in Table 1 compiled for BEC Associates by A. I. Olayinka and O. O. Kehinde-Phillips (1993).

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TABLE 1: MINERAL RESOURCES OF NIGERIA

S/N	Non-Metallic Minerals	State Occurrences	Location	Industrial Uses	Users	Level of Development	Reserve (tons)	Project of Uses	Quantity Needed as Industrial Input (Tons)	Industries that require them	Source		Remarks
											Local	Imported	
1.	Asbestos	Kaduna, Kastsina, Niger	Sherni, Tegina, Daboe	Short fibre in asbestos cement products, asphalt and vinyl tiles, insulation and gaskets, electrical appliances, battery	Asbestos, Ceramics Refractory and Glues	Partial preliminary exploration	Medium Quantity		199,300		100%		Detailed studies required to determine economic viability
2.	Baryte	Benue, Plateau, Sokoto, Gongola, Enugu, Cross-River	Benue, Mahardi Abuthi, Gboko, Ibi, Igbor, Kwano-Akir Akire-Ware Azare, Shata, Abuthi Akire, Ware, Kwano, Gboko, Abuthi-Akir, Ibi, Dungel, Lafin	Pigment or extender Oil-well drilling insert filler in the production of oil cloth, linoleum, paper, and plastics; a weighting materials for textiles and leather; as flux in brass melting. Chemical industries use barites for the manufacture of barium compounds such as chloride, nitrate, carbonate, hydrate and sulphide.	Oil-industries (Drilling fluid (Mud)) Foam dry.	Present production level is only about 10% of demand. Production capacity at Azara to be increased.	730,000 Azara deposit can satisfy Nation's demand for 20 years. Others not yet determined		Drilling fluid 90,000				Except for Azara in Plateau, all the other deposits are not yet quantified
3.	Barite	Gongola, Cross-River, Ondo, Benue, Bendel, Plateau, Oyo	Ekiti, Oyan, Mahin Plateau	Manufacture of Electrical components with temperature Alumina for refractories, used as aluminium or abrasives.	Ajaokuta Steel	Not yet explored.	Not yet known		Ajaokuta Steel alone 13,000		100%		Urgent exploration should be initiated. Alumin refraction are wholly imported.
4	Clay-Ball Clay	Imo, Bendel, Akwa-Ibom, Rivers, Cross-River, Ondo, Enugu, Anambra	Akukuku, Kano, Benue, Buan and Kwawen, Iguoriak, Abeh, Uzare, Ekei, Ditsen	Domestic ceramic wares and building construction, Pottery, electrical porcelain, floor and wall tiles, refractory products, ceramic glazes and porcelain enamel slips.	Ceramic industries at Umuahia, Quality ceramics, Uyo.	Deposits meet demands of existing ceramic industries can also accumulate additional ores. Detailed evaluation of all deposits required and researches into method of refining them.	Very large up to 5,000,000		5,000,000				Partial preliminary exploration and evaluation. Small scale exploration of some deposits.
5.	Kaolin Clays	Enugu, Anambra, Imo, Kano, Plateau, Kaduna, Kaduna, Ogun Sokoto, Abia, Akwa-Ibom, Cross-River, Bauchi	Abakaliki, Awgu, Udi, Ezza, Ngbo, Ogbe, Nkwo, Onitsha, Ogbaji, Okpa, Abia, Abiguna, Ihiala, Okija, Ozubulu, Aguleri, Ito, Orlu, Ejeje-Bat, Kaskara, Mahum Farah, Arkella, Ife.	Paper making, rubber, plastics, paints, white sanitary ware, pharmaceuticals, white tiles, insulator, ware, refractories, crayons, pencils, cement, fertilizers, textile, insecticides, polishes, ultra-marines, oil cloth.	Nigerian Mining Corporation Jos, African Mining Corporation, Kaduna, Ceramic Industries, Chemical Industries, Textile Industries.	Full evaluation of all deposits, refining/ beneficiation process to be undertaken.	976,000,000		253,000	Paints Ceramics	Local, Partly			

S/N	Non-Metallic Minerals	State Occurrences	Location	Industrial Uses	Users	Level of Development	Reserve (tones)	Projected Uses	Quantity Needed as Industrial Input (Ton)	Industries that require them	Source		Remarks
											Local	Imported	
9.	Feldspar	Benue, Kwara, Oyo, Kaduna, Niger, Kwara, Borno, Oyo, Ogun	Akwari, Arufu, Buri Alawain Egbe, Okene in Kwara State. Bari, Alawa in Niger State, Owoza in Borno State, Osogbo in Osun State; Abeokuta in Ogun State.	Hydro-chemical acid production glass, ceramics, glasses, metallurgical fluxes, Glass manufacture, Ceramics, Filters in paint Industries, Terrazo and tiles manufacture, Road construction and building projects.	Glass Industry, Ceramic industry, Chemical industry, Construction industry.	Not yet developed, Partial exploration and evaluation Need processing outfits. Have potential of meeting demand locally.	Not yet known; Not yet quantified.		25,000 5,000	Glass Industry, Ceramics	80% 20%		
10.	Flouspar (Flourite)	Benue, FCT	Akwana, Arufu in Benue State, Benue Valley	Hydro-chemical acid production glass, ceramics, enamels and ferrous metallurgical fluxes	Chemical Industry, Glass industry, Ceramic industry, Iron & Steel industry	Partial investigation	Not yet quantified						
11.	Garnet in conjunction with Rubi	Plateau	Keffi, Akwanga Nasarawa	Abrasives paper, gems, cleaning and polishing agents – Sandblasting	Petroleum industry		Not yet quantified						
12.	Graphite	Niger State, Kaduna State, Gongola State, Bauchi and Sokoto States.	Alawa in Niger State, Biri Gwari in Kaduna State, Majo, Butale, Gyam, Jauro, Jelo in Gongola State, Haya in Bauchi State	Graphite Crucibles, Lubricants, pencil lead, carbon brushes and foundry facings.	Foam Dry, Electrical Industry, Chemical industry		In large quantity but not yet quantified.						
13.	Gypsum	Borno, Sokoto, Gongola, Enugu, Anambra, Ogun, Bendel, Benue, Bauchi, Kaduna, Kaduna, Niger, Oyo	Potiskum Damboa in Borno State, Wurno, Gada, Kalcamajei in Sokoto State, Maugiroe shelling in Gongola State, Oji, Ofo, in Enugu State, Awka, Onitsha in Anambra State; Gombe, Kanawa, Filiya, Gub-Zardin in Bauchi, Awgu, Otukpo in Benue Valley, Maiduguri in Borno, Adamawa in Gongola State.	Manufacture of Cement, paint manufacture, paper and ceramic industry/industries. Manufacture of ceiling bands, dental plasters, school chalk, art casting plasters and pharmaceuticals, Fertilizer.		Small scale mining in Sokoto and Potiskum. Partial exploration and evaluation. Present production is less than 10% of national requirement.	Large but not yet known		286,000	Cement Chalk & Crayon construction Pharmaceuticals	20% 80% 80% 20% - 100% - 100% 20% 80% 80% 20% - 100% - 100%		Detailed exploration and evaluation required. Need to increase the scale of Mining at Sokoto and Potiskum.
14.	Kyanite	Kaduna, Niger	Birni Gwari, Masuku, Meguga Kuta	Refractory, manufacture of refractory motares, Cement mixes		Partial investigation. Further studies required to assess economic viability of reported deposits.	7,000,000 Others yet to be quantified.						

S/N	Non-Metallic Minerals	State Occurrences	Location	Industrial Uses	Users	Level of Development	Reserve (tones)	Projected Uses	Quantity Needed as Industrial Input (Ton)	Industries that require them	Source		Remarks
											Local	Imported	
6.	Fire-Clay Refractory	Enugu, Anambra, Imo, Katsina, Ogun, Sokoto, Ondo, Plateau	Obuya, Nugu, Nnewi, Auchi, Okigwe, Katsina, Akure, Abeokuta, Jos, Kamba, Sokoto	Refractory metal/Ugy Bricks 7	Foundaries Cement Producers	Detailed beneficiation studying pilot projects are needed to produce acceptable aluminsilicate refractories. Care achieved, the demand for such refractories can be fully sourced locally.	20,000,000		1,400,000				
7.	Diatomite	Bornu	Bornu, Abakire, Balarabe, Bilaraba, Gujba	For preparing insect pest control, filter medium, polishing compound. Filtering agent in the clarification of sugar, fruit juices, oils and in brewing. In heat and sound insulation in the form of bricks or loose powder, as a poronsextender and flatting agent in paints as a dustling agent to prevent the caking of fertilizers containing ammonium nitrate and as filler in light-weight concrete rubber, goods and peer, also used in pvc pipes, roofing sheets, etc., As a catalyst carrier chromatographic support, polish abrasive and pesticide carrier.	Chemical Industries	More detailed exploration and evaluation required Pilot production required to establish viability and suitability of the deposits	In large commercial quantities 10,000,000						
8.	Dolomite Marble/Magnesia	Kwara, FCT, Niger, Bendel, Benue, Oyo, Plateau, Kaduna, Ondo	Jakura, Elebu, Ajaokuta, Osara, Burum, Taka Lafia, Kwakuti, Ukpilla, Udo, Igara, Ikpeshi, Robe, Igbeti, Toto-mura Eill, Kankara, Ido-Ani	Refractories-Refractory bricks. In refractories, chemical industries, cement manufacture flux in steel making and in Petroleum Industry. Road building. Used for metallurgical processes.	Steel Industries Glass industries, Cement industries, Petroleum industry, Petrochemcial industry, Foundaries	More studies/production of $CaCo_3$ based chemical required. Production of decorative marble to be initiated. Local deposits capable of meeting national demands if both mining and chemical related Industries are fully developed.	8,000,000 FCT; 2,000,000 Kwara; 7,000,000 Niger; Igbeti – 149,000,000 Others not yet determined						Other deposits but not adequately explored. Standard Lab. Tests to determine chemical composition. Further geologic mapping to determine reserves.

S/N	Non-Metallic Minerals	State Occurrences	Location	Industrial Uses	Users	Level of Development	Reserve (tones)	Projected Uses	Quantity Needed as Industrial Input (Ton)	Industries that require them	Source		Remarks
											Local	Imported	
20.	Quartz	Plateau, Borno	Pankshin, Biu	Piesoelectric crystals, optical uses	Ceramics	Pitting, trenching and granulometric analysis	20,000 others not quantified		59,500	Ceramics			
21	Salt	Plateau, Enugu, Cross-River, Rivers	Awe, Abakaliki, Okpesi, Uburu	Foodstuff uses, uses in agriculture and industrial, chemicals, textile, industrial soap and explosives, production of chlorine	Agrochemical and Fertilizer	Partial investigation	Not yet known		380 3.4 340 8,750	Agrochemicals and Fertilizers Cosmetics and Toiletries Pharmaceuticals Soaps and Detergents			
22.	Sand	Ondo, Kwara, Plateau, Enugu, River, Edo, Lagos, Ondo, Rivers, Sokoto, Niger, Imo, Ogun, Kaduna	Ijero, Lokoja, Shehu, Pankshin, Nsukka, Enugu, Nsude, Port-Harcourt Ughelli, Apapa, Lagos, Ondo, Igbekebo, Insert Igbokoda, Afam, Sokoto, River, Mokwa, Bida, Azumini River, Ijebu-Ode, Ilaro, Daura	Foundry sand, Ceramics, manufacture of glassware		Most have been partially investigated and evaluated. Deposit meet industrial requirement and can support more.	6,5000,000 others not yet quantified but very large	Deposit have potential to replace imported sand for gravel pack.					
23.	Sulphur	Sulphur can be obtained from lead-zinc smelting. Lead-zinc ore is found in Enugu and Plateau		Sulphuric acid production insecticides, paper, rubber and plastics			Not yet quantified						
24.	Talc	Niger State, FCT, Oyo, Kwara, Kaduna, Ondo	Kumunu, Tegina, Maru, Shagamu, Ife, Ilesha, Iseyin, Okolon, Zongwa, Ijero Ekiti, Odogbe	Used in paint, cement, toiletries, Furnances, Ceramics and insecticides	Chemical industries cosmetic industries	Partial preliminary investigation, Geological drilling mapping, laboratory and analysis	40,000,000. Others not yet known		2,500 1,000	Cosmetics, Foam Dry Paints	100% 100%		Detailed reserve studies required. Deposits may satisfy National demand when fully exploited and processed.
25.	Trona (Soda Ash)	Borno, Gongola, Kano	Gashua, Nguru, Geidam, Belwa, Zumo.	Manufacture of glass, Chemicals, Caustic soda and clearisers. For production of alumina, paper and petroleum refiring, crayon manufacture, mercezing cotton and water treatment.	Glass industry, Chemical industry Refractory industry, Paper industry and Petroleum industry	Need for detailed mapping, drilling and laboratory tests on the deposits. Mining is on small scale.	Large commercial quantity		20,500 500	Glass industry Cosmetics	50% 100% 50%		

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S/N	Non-Metallic Minerals	State Occurrences	Location	Industrial Uses	Users	Level of Development	Reserve (tones)	Projected Uses	Quantity Needed as Industrial Input (Ton)	Industries that require them	Source		Remarks
											Local	Imported	
15.	Limestone	Cross-River, Kwara, Benue, Niger, Kwara, FCT, Sokoto, Bauchi, Gongola, Enugu, Abia, Edo, Ogun Ondo	Mfamosing, Udo, Jakura, Igumale, Igumale, Ogbolokuta Yandev, Itobe, Kwakuti, Elebu, Purum, Kalambana, Gombe, Numan, Nkalagu, Odomoke, Arochukwu, Ukpilla, Ewekoro, Sagamu, Okolase-close to Ifon,	Cement Manufacture fluxing stone for iron ore smelting, filter in Petrochemical, lime production plant	Cement Industry/ies Petro-chemicals	Most are being exploited	20,000,000 20,000,000 20,000,000 10,161,000 5,080,00(67,059,000 68,900,000 101,605,000 702,000,000 200,000,000 101,000 000 7,135,000 some not yet quantified 7,500,000		7,830,000 3,000 20,000 1,000 200,000 1,300,000 900,000	Cement Fertilizer Glass Paints Asbestos Constructio n Iron & Steel	100% - 100% - 100% - 100% - - 100% - 100% 100% - 100% - 100% - 100% - - 100% 100% -		Deposits exceed requirement s of Cement Industries. Studies Production of fluxes should be intensified.
16.	Lignite	Bauchi, Anambra., Enugu, Abia, Delta, Imo	Gombe, Oba Nnewi, Biala, Ozimo, Inyi, Umuahia, Ogawashi, Obunkpa, Orlu, Umuigbo, Ogidi River	Fuel, Tar Oil, Gases, Production of Nitrate Fertilizer			Not yet quantified						
17.	Coal	Enugu, Benue, Plateau, Bauchi, Gongola, Abia, Delta	Enugu, Ezimo Inyi, Udi, Ogbe, Uturu, Ogboyoga, Okaba, Orukpa, Okpoga, Dekina, Otukpa Lafia/Obi, Dunja, Gombe, Maogunga/garin, Kumo, Kolori, Doho, Molko, Ngurore	Fuel, manufacture of tar, gases and oils, industrial chemicals, graphite molecular sieves, activated carbons, re-carbonization materials, ammonium compounds, paraffins, olefins, wax and pitch, calcium carbide.	Steel Mills	Some deposits are already being exploited establish pilot and industrial scale work to confirm economic feasibility of coal blending to produce metallurgical coke.	458,000,000		2,515,000	Iron & Steel			Needed for further research
18.	Mica	Bauchi, FCT, Plateau, Kwara, Cross River, Benue, Katsina, Niger	Duku, Burum, Kaffi, Kabba, Egbe, Oba, Hills, Zaria, Niger	Electrical insulation. electronic tubes and capacitors, roof and paper coatings, varnishes, porcelain cosmetics	Ahamabbey. Ass. Manufacturing Co. Ltd., Kano. Chesebrough Prod Ltd, Isolo Industrial Estate controlled Plastic Ltd. Kano Cutter Hammer Ltd, Isolo Expressway. Cybele cosmetics Ltd., Maduin, Daily Needs Chemists, Del Stella Nig. Ltd., Ikeja Industrial Estate		Not yet quantified	Electronic/Electrical Industries		Electrical/ Electronic Industries			
19	Phosphate	Sokoto, Ogun, Enugu, Imo, Bendel	Sokoto, Kano Valley, Ilo Talasse, Ilaro Abeokuta	Fertilizer, Phosphoric Acid, Phosphorus Acid	Fertilizer Industry	Full exploration and evaluation in progress	Not quantified 20,000,		Phosphoric Acid 90,540 Phosphate Rock 120,000	Fertilizer Industry	100%		

S/ N	Metallic Minerals	State Occurrences	Location	Industrial Uses	Users	Level of Development	Reserve (tones)	Projected Uses	Quantity Needed as Industrial Input (Ton)	Industries that require them	Source		Remarks
											Local	Imported	
1.	Cassiterite (Tin ore)	Plateau, Kaduna, Kano, Bauchi	Jos, Zaria, Bauchi, Kano	Tin plating, can production Calico-printing, dyeing, ceramics, Hardening of corper and lead in alloys. Used in collapsible tubes soldering bearing.	Tin smelting Electrical Industry	Detailed geological investigation and Laboratory analysis. Paleogeographic mapping. Geophysical investigation of old buried river channels.	143,000,000	Tin oxide vesostors Electrical lead wires and printing circuits	30,000	Tin smelting Electrical Industries	100%		
2.	Columbite	Bauchi, FCT, Kano, Katsina, Kwara, Niger, Benue, Ogun, Plateau Akwa-Ibom, Oyo, Kogi	Bauchi, Benue, Fusaka, Zaria, Kano, Ririwa, Kabba, Ilorin Jos, Plateau, Ijero, Osu Sepeteri, Lawo-Ile, Komu, Egbe, Udegi	Source of Niobium and Tantalum ferro-alloys, Special steels, electronic tub filaments, in rockets and aircraft manufacture nuclear reactors. High temperature alloys for jet engines, Gas turbines and rockets; used in vacuum tubes and radio valves.			45,000,000 Most deposits nct yet quantified						
3.	Galena	FCT, Niger	Babasanmi, Izom	Sources of lead, batteries, Eletrical cables, ammunition, paint, ceramics		Detailed geological mapping, drilling, sampling and Lab. Analysis.	Not yet quantified						
4.	Gold	Sokoto, Oyo, Edo, Kaduna, Kano, Kwara, Niger	Zamfara, Malemale, Ileha, Iperindo, Igarra, Birni-Gwari Kano, Kabba, Kainji, Minna, Kaduna, River	Jewellery and ornaments, dental and medical supplies, electronics, industrial applications. Coinage and High technology applications.			Not yet quantified.						
5.	Ilemite	Plateau, Kaduna, Kano, Kwara		Steel Manufacture and Engineering works with other mineral like Manganese, Nickel, etc.									

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S/ N	Non-Metallic Minerals	State Occurrences	Location	Industrial Uses	Users	Level of Development	Reserve (tones)	Projected Uses	Quantity Needed as Industrial Input (Ton)	Industries that require them	Source		Remarks
											Local	Imported	
26.	Bentonite (Bentonite Clay)	Gongola, Borno	Gashua, M/Balwa	Crayons, Pharmacy, Cosmetics, Agriculture, Polishers, Water paints, Textiles.			Not yet quantified		140,500	Oil Industry	100%		
27.	Magnesite (Magnesium can be obtazined)	Gongola	Garkida	Refractory	Foundry		Not yet quantified						
28.	Tourmaline	Niger Plateau	Kumunu, Keffi	Gemstone – Jewelry in abrasives, manufacture of surface testing equipment, lectronics			Not yet quantified but very large and in commercial quantities						There are no cutting and polishing industries in the country.
29.	Emerald	Plateau	Keffi	Electronics									
30.	Rock Crystal	Plateau	Jos										
31.	Topaz	Plateau	Jos	31.	Topaz								
32.	Flouspar	Plateau	Jos	32.	Flouspar								
33.	Aquamarine	Jem'a Kaduna	Jem'a	33.	Aquamarine								
34.	Ruby	Kaduna											
35.	Sapphire	Kaduna											
36.	Amethyst	Katsina, Bauchi	Zaria, Dala, Panamadina, Hange Hills, Balewa										
37.	Garnet		Various localities										
38.	Decorative Rocks	All over the States		For decoration and construction	Construction companies		Very large						

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S/N	Metallic Minerals	State Occurrences	Location	Industrial Uses	Users	Level of Development	Reserve (tones)	Projected Uses	Quantity Needed as Industrial Input (Ton)	Industries that require them	Source		Remarks
											Local	Imported	
10.	Monazite	Plateau, Kaduna, Kano, Bauchi		In spark lighters, gas mantles, colour television and other industrial uses									
11.	Pyrochlorite	Kano, Plateau											
12.	Butile	Plateau, Kaduna, Bauchi		Sources of Titanium stainless and special steels for dies and tools. Military hardware, Industry and Pottery fillers in paints and textile industry.									
13.	Thorite	Plateau											
14.	Wolframite	Kaduna	Banki	Source of walfram. Electrical (bulb) lighting, electronic – electrical contact parts			In commercial quantity but not yet quantified						
15.	Zircn	Plateau, Kaduna, Ondo	Jos, Odegi, Ekiti	In various alloys manufacture. Nuclear reactors, flask, lamps, refractory foundry materials, abrasives, gemstones.		Traces. More areas to be investigated.							
16.	Vanadium	FCT	Abuja	Alloying agent increases strength and resistance									
17.	Nickel	Oyo	Ife-Ilesha Hilima Tanko	Imparts toughness and resistance to heat and acids									
18.	Chromite	Sokoto	Ruan De rue	Imparts hardness and prevents rust.									

S/N	Metallic Minerals	State Occurrences	Location	Industrial Uses	Users	Level of Development	Reserve (tones)	Projected Uses	Quantity Needed as Industrial Input (Ton)	Industries that require them	Source		Remarks
											Local	Imported	
6.	Iron Ore	Kwara, Plateau, Kwara	Itakpe, Muro Hills, tot, Ajabanako, Chokochoko, Tijani,			Carry out Pilot plant (exploited) investigation investigated	310,000,000 Not yet determined, 60,000,000 20,000,000 2,000,000		5.9 - 8.4 million tones from 1990-1995	Iron and Steel plants			
		Benue, Sokoto, Bauchi, Borno, Enugu, Kwara, Kaduna	Agbaja, Kanana			Further Investigation	Not yet quantified						
		Oyo	Egbinija, Dakingari, Kishi, Karfa, Nsude, AgbadooOkudu Tijani				60,000,000 24,000,000						
			Ajabe, Egborin, Gbede, Otamokun, New Ogbomoso										
7.	Lead Zinc	Kano, Plateau, Enugu, Abia, Benue, Bauchi, Gongola, Oshun	Rifiwai, Zuru, Wase, Abakaliki, Ohaozara, Ishiagu, Gwona, Arufu, Ibi. Wakaye near Apomu	No storage batteries Electrical cables, Ammunitions Pipes, pigment in Paints and ceramic industries coating steel products and Die casting alloys with lead, copper, aluminium for various industrial applications.		Detailed geological mapping, drilling, sampling and laboratory analysis	Not yet quantified						
8	Manganese	Kaduna State, Niger, Cross River	Tundun Kudu, Mallum Ayuba Birni Gasari Gumi	Alloy in Steel making Industries, Dry cell and Chemicals			200,000 Others not yet quantified						
9	Molybdenum	Plateau, Plateau, Bauchi, Bauchi, Ondo	Kigom Hills, Nasarawa Egon Dagon Daji, Tibobi Hills, Ikare Ekiti	Special steel, manufacture of dye radio equipment. Chemical industry and Foundries		Traces. To be further investigated.	Not yet determined						

These minerals may be classified as follows:

A. MINERAL FUELS

Coal was one of the first minerals to be economically mined in Nigeria. It was first discovered in 1909 and mined in 1915. Over 2.74 billion tones of Sub-bituminous coal are inferred in Anambra, Nassarawa, Ondo, Adamawa, Delta, Edo, Ebonyi, Gombe, Imo, Kwara, Bauchi and Plateau States. Nigeria's proven coal reserves now stand at about 640 billion metric tonnes. These figures were given by the Managing Director of Nigeria Coal Corporation, Professor Pius Okeke, in the COMET of Monday, April 29, 2002. There are three underground coal mines namely: Okpara, Onyeama and Owukpu in Enugu, in Enugu State and Kogi States respectively while there is an open cast mine at Okaba – Odagbo in Kogi State.

The Nigerian coal has a sulphur content of less than 1% and low ash contents. These properties make the coal environmentally friendly and hence it is a foreign exchange earner.

The Lafia-Obi Coal has coking properties and can be blended with other coals to produce the required quality for use in the blast furnace at Ajaokuta.

Over 70 million tonnes of lignite has been recorded in Edo and Delta States. Coal is used as fuel. It is also used in the manufacture of tar, graphite, re-carbonization materials, paraffins, Wax and pitch among other uses.

Uranium: Occurrences of Uranium have been discovered in Akwa Ibom, Bauchi, Plateau, Kano and Taraba States. Pyrochlore which contains 3.3% Uranium oxide, 3.3% thorium oxide and 41.1% niobium and tantalum oxides occur in the Liruei Hills in Kano State. The Nigerian Uranium Mining Company (NUMCO) has been established for exploration of Uranium in Nigeria. Uranium is a radioactive mineral finding extensive use in nuclear plants.

Crude Oil and Gas: Nigeria has huge reserves of oil and gas. Petroleum provides the main source of government revenue and foreign exchange. The reserve of Crude petroleum is currently put at 32 billion barrels and government plans to increase this to 40 billion barrels by 2010. The gas reserve is estimated at about 159 trillion cubic meters. These figures were recently revealed by Miss Pepple, Permanent Secretary,

Ministry of Petroleum Resources. (PUNCH, March 22). Petroleum products will continue to remain the mainstay of the Nigeria economy as long as the Nigerian government continues to neglect the development of the solid minerals.

Table 2 gives a list of domestic petroleum products.

TABLE 2: DOMESTIC PETROLEUM PRODUCTS

1. Premium Motor Spirit (PMS)
2. Automotive Gas Oil (AGO)
3. Liquefied Petroleum Gas (LPG)
4. Deodorized Kerosene Gas
5. Dual Purpose Kerosene (DPK)
6. Aviation Turbine Kerosene (ATK)
7. Naphta
8. Low Pour Fuel Oil (LPFO)
9. High Pour Fuel Oil (HPFO)
10. Asphalt (Six Grades)
11. Base Oil (Six Grades)
12. Wax
13. Sulphur

B. IRON DEPOSITS

The Iron and Steel Industry is the catalyst for the industrialization of any country. Two major steel plants have been set up at Ajaokuta in Kogi State and Aladja in Delta State. Both plants have been planned to consume about 3.5 million tones of Iron concentrates annually. At full production capacity, Aladja requires annually:

(i) 1.55 million tonnes of iron ore
(ii) 800,000 tonnes of Coke
(iii) 130,000 tonnes of limestone
(iv) 50.000 tonnes of refractories

while Ajaokuta requires annually: -

(i) 2 million tonnes of iron concentrates
(ii) 1,200,000 tonnes of Coke
(iii) 650,000 tonnes of limestone
(iv) 255,000 tonnes of dolomite
(v) 70,000 tonnes of refractories.

The main raw material is iron ore which is available in Kogi, Anambra, Oyo, Plateau and Sokoto States. Table 3 shows the major iron deposits in Nigeria.

TABLE 3: MAJOR IRON DEPOSITS IN NIGERIA

Location	State	Reserves in Tonnes	Grades (% fe)	Remarks
Agbaja Plateau	Kogi	30,300,000	0	
Itakpe Hill	Kogi	300,000,000	37.65	
Nsude/Enugu	Anambra	40,000,000	40	
Ajashe	Oyo	102,000	40	
Muro Hill	Plateau	10,000,000	31.6	
Ajabanoko	Kogi	60,000,000	32	
Kanana	Kogi	2,000,000	31.5	
Kebbi	Sokoto	42,879,200	38.0	Kehinde Phillips & Nurudeen (1997)
Yabo	Sokoto	402,861,890	40	Kehinde Phillips & Nurudeen (1997)
	Sokoto	107,563,460	40	Kehinde Phillips & Nurudeen (1997)

Kehinde-Phillips and Nurudeen (1997) carried out extensive mineral exploration of Sokoto State. Limonitic iron ore deposits were discovered in various localities as indicated in Table 3 above. The reserves of these deposits were calculated and amount to 594,605,030 tonnes with grades of between 32% and 40% Fe. Iron ore is the major raw material for the Steel industry, metallurgical and rolling mills and foundries.

C. CERAMIC MATERIALS

Clays: Extensive deposits of Clay are ubiquitous. They are known in several places in Nigeria including Tade near Omi-Adio, Oyo State first discovered by Olayemi and Kehinde-Phillips (1973). It had a reserve of 1,524,000 tonnes. Other deposits occur at Mararaba – Rido in Kaduna State, Jos and Maiduguri. These clay deposits find extensive use in the pottery and Brick industries.

Kaolin: Kaolin deposits are found in several areas of the country. Important deposits of Kaolin are distributed as shown in Table 4.

TABLE 4: DISTRIBUTION OF KAOLIN DEPOSITS

No.	Location	State	Reserves in Tonnes	Remarks
1.	Ozobulu	Anambra	24,200,000	
2.	Kankara	Kaduna	3,400,000	
3.	Ifon/Omiafara	Ondo	40,000,000	
4.	Sabro, Lambani	Sokoto	1,092,000	Kehinde Phillips & Nurudeen (1997)
5.	Goronyo	Sokoto	2,878,483	Kehinde Phillips & Nurudeen (1997)
6.	Illela	Sokoto	693,030	Kehinde Phillips & Nurudeen (1997)
7.	Ibese	Ogun	3,900,000	Kehinde Phillips (1997)
8.	Bamajo	Ogun	Large	
9.	Onibode	Ogun	Large	
10.	Lisabi	Ogun	Large	

Kaolin finds uses in paper making, rubber, plastics, paints, white sanitary wares, white tiles, pharmaceuticals, crayons, pencils among others.

D. METALLURGICAL AND REFRACTORY MINERALS

The main characteristic of refractory materials is their ability to withstand high temperatures employed in metallurgical furnace. These refractory minerals include dolomite, limestone and fireclays. Dolomite is used in the manufacture of steel, in construction and glass industries. In steel manufacture, dolomite and marble are used as fluxes. Known deposits of dolomite/marble occur at Jakura, Osara, Elebu, Igbeti, Burum, Ukpilla, Ubo and Kwakuti. Fire Clay deposits are found in the Lower Coal Measures at Enugu, Obuya, Okigwe, Abeokuta and Akure. Limestone deposits are known in several places and include Nkalagu, Ugep, Mfamosing, Yandev, Ewekoro, Sagamu, Kalambina, Ahaka, Ogbolokuta and Kanawa, among others. The reserves range between 5,080,000 tonnes at Ogbolokuta to 135,000,000 tones at Ewekoro. Large deposits of marble are available at Ukpilla, Kajura and Igbeti as well as at Elebu, Kankara, Toto Muro Hill, Ubo, Elebu and Itobe among other places.

Limestone: Table 5 shows the major deposits of limestone in Nigeria.

TABLE 5: DISTRIBUTION OF LIMESTONE DEPOSITS

No.	Location	State	Reserves in Tonnes	Remarks
1.	Nkalagu	Anambra	11,000,000	
2.	Odomoke	Anambra	64,011,000	
3.	Mfamosin	Cross River	20,000,000	
4.	Igumale	Benue	110,161,000	
5.	Yandev	Benue	67,059,000	
6.	Ewekoro	Ogun	135,000,000	
7.	Sagamu	Ogun	170,000,000	
8.	Ashaka	Bauchi	68,000,000	
9.	Wammako	Sokoto	101,605,000	
10.	Bodinga	Sokoto	11,952,443	Kehinde-Phillips & Nurudeen (1997)
11.	Shagari	Sokoto	3,368,400	Kehinde-Phillips & Nurudeen (1997)
12.	Wurno	Sokoto	20,358,968	Kehinde-Phillips & Nurudeen (1997)
13.	Dangeshuni	Sokoto	17,593,352	Kehinde-Phillips & Nurudeen (1997)

In addition to cement manufacture, limestone is also used in lime production, filler in Petrochemicals and as fluxing stone for iron smelting.

(ii) Marble:

The major deposits of marble are illustrated in Table 6. Marble occurs widely in Kogi and Edo States. The deposit at Ukpilla is quarried mainly for Cement manufacture. The Jakura marble is cut and polished for ornamental purposes.

TABLE 6: MAJOR MARBLE DEPOSITS IN NIGERIA

No.	Location	State	Type	Reserves in Tonnes
1.	Jakura	Kogi	Calcite	46,738,000
2.	Burum	FCT	Dolomite	4,572,000
3.	Kwafi	Niger	Dolomite	2,540,000
4.	Taka Lafia	FCT	Dolomite	4,000,000
5.	Ukpilla	Edo	Calcite	10,161,000
6.	Ubo	Edo	Calcite	22,353,000
7.	Igbeti	Oyo	Dolomite	40,000,000

E. FERTILIZER MINERALS:
Included in these are mainly phosphate and gypsum.

(i) Phosphate:
Table 7 shows the distribution of known phosphate occurrences and deposits in Nigeria

TABLE 7: PHOSPHATE RESOURCES OF NIGERIA

No.	Location	State	Type	Reserves in Tonnes	Remarks
1.	Ifo	Ogun	Granular	Traces	
2.	Oja-Odan	Ogun	Nodular	Traces	
3.	Oshosun	Ogun	Vessicular	Traces	
4.	Abakaliki	Imo	Nodular	Traces	
5.	Bodinga	Sokoto	Vesicular	2,720,439	Kehinde-Phillips and Nurudeen (1997)
6.	Shagari	Sokoto	Nodular/Vesicular	1,548,261	Kehinde-Phillips and Nurudeen (1997)
7.	Gwadabawa	Sokoto	Vessicular/Nodular	3,216,915	Kehinde-Phillips and Nurudeen (1997)
8.	Wurno	Sokoto	Vessicular/Nodular	5,464,730	Kehinde-Phillips and Nurudeen (1997)
9.	Kwre	Sokoto	Nodular/Vessicular	2,059,776	Kehinde-Phillips and Nurudeen (1997)
10.	Dangeshumi	Sokoto	Vessicular/Nodular	6,881,093	Kehinde-Phillips and Nurudeen (1997)
11	Gada	Sokoto	Nodular/Vessicular	2,574,391	Kehinde-Phillips and Nurudeen (1997)

The industrial uses of Phosphate include: manufacture of fertilizer and phosphate acid.

(ii) Gypsum:

The phosphate deposits/occurrences are usually associated with Gypsum.

Table 8 shows the Gypsum resources of Nigeria.

TABLE 8: GYPSUM RESOURCES OF NIGERIA

No.	Location	State	Reserves in Tonnes	Remarks
1.	Oshosun	Ogun	Traces	
2.	Bodinga	Sokoto	2,317,403	Kehinde-Phillips and Nurudeen (1997)
3.	Shagari	Sokoto	1,318,889	Kehinde-Phillips and Nurudeen (1997)
4.	Gwadabawa	Sokoto	868,227	Kehinde-Phillips and Nurudeen (1997)
5.	Wurno	Sokoto	4,654,971	Kehinde-Phillips and Nurudeen (1997)
6.	Kwre	Sokoto	1,754,624	Kehinde-Phillips and Nurudeen (1997)
7.	Dangeshumi	Sokoto	5,861,612	Kehinde-Phillips and Nurudeen (1997)
8.	Gada	Sokoto	2,193,999	Kehinde-Phillips and Nurudeen (1997)

F. INDUSTRIAL AND MANUFACTURING MATERIALS

Included in these are glass, sands, talc, baryte, asbestos, diatomite and mica.

(i) Glass Sands

The Chief constituent of glass is silica sand and minor Constituents are Soda and Lime. Glass sands have a silica content of 95 to 98.5% but the impurities are important since they determine the type of glass produced.

Table 9 shows the distribution of Glass sands in Nigeria.

TABLE 9: DISYTRIBUTION OF GLASS SANDS IN NIGERIA

No.	Location	State	Reserves in Tonnes	Type of Glass Expected	Remarks
1.	Igbokoda	Ondo	Very Large	Colourless bottles and windows Flint glass II, Sheet glass II	
2.	Victoria Island	Lagos	1,560,000	Green Glass and Amber glass	Kehinde-Phillips et al (1999)
3.	Ijebu-Ife	Ogun	264,000	Bottle Glass I & II Amber glass I & II	Kehinde-Phillips and Agoro (1999)
4.	Apapa and Badagry	Lagos	Very Large		
5.	Gudu (Balle, Kurdala, Bailaka)	Sokoto	3,448,500	Colourless Bottles and Windows	Kehinde-Phillips & Nurudeen (1997)
6.	Sabon Birni	Sokoto	342,000	Colourless Bottles and Windows	Kehinde-Phillips & Nurudeen (1997)
7.	Isa	Sokoto	256,500	Colourless Bottles and Windows	Kehinde-Phillips & Nurudeen (1997)

8.	Afam	Rivers	Very Large	Windows, Containers and coloured bottles.	
9.	Ughelli	Delta	Very Large	Colourless Bottles and Windows	
10.	Bida, Mokwa, Lafiaji	Niger	Large	Coloured and amber glass	

(ii) Talc:

Talc is the major non-metallic mineral requirements of the cosmetic industry. Economic deposits of talc occur extensively in Nigeria in arrears such as Apomu, Ilesa, Wonu, Iseyin, Ijero-Ekiti, Odogbe, Tegina, Maru and Kumunu. The Deposit at Kumunu in Niger State has a reserve of 40 million tonnes. Table 10 shows the distribution of talc deposits in Nigeria.

TABLE 10: DISTRIBUTION OF TALC DEPOSITS

No.	Location	State	Reserves (in Tonnes)	Remarks	Uses
1.	Kumunu	Niger	40,000,000		Manufacture of Cosmetics, paints, toiletries, insecticides, leather making, Crayons, lubricants, furnaces and ceramic
2.	Apomu	Oshun	10,000,000	Kehinde-Phillips (1973); Elueze (1982)	
3.	Ijero-Ekiti	Ekiti	Large		
4.	Odogbe	Oyo	Not Known		
5.	Tambawal	Sokoto	372,000	Kehinde-Phillips & Nurudeen (1997)	
6.	Tangaza	Sokoto	1,092,000	Kehinde-Phillips & Nurudeen (1997)	
7.	Goronyo	Sokoto	2,878,483		
8.	Illela	Sokoto	693,030	Kehinde-Phillips & Nurudeen (1997)	

(i) Baryte:

Baryte is a vital component of the drilling mud in the oil industry. It occurs in substantial quantity in Plateau, Gongola, Benue and Cross-River States. The Azara deposit in Plateau State has a reserve of 730,000 tones. In addition to its use as component of drilling mud, baryte can also be used in the manufacture of paints, glass and paper.

(iv) Mica:

Mica is a group name for several minerals familiar to the layman, because of its uncommon cleavage which allows the minerals to split into thin sheets. Mica is used extensively in the electrical industries because of its form and physical properties. Mica occurs in many places in Nigeria, including Dukku in Bauchi State, Keffi in Plateau State, Egbe and Kabba in Kogi State, Oban Hills in Cross River State and Zaria in Kaduna State. These minerals are not yet quantified.

(v) Asbestos:

Fair reserves of asbestos occur in the Schist belt at Mallam Tanko and at Shemi in Kaduna State, Tugun in Katsina State and Dutse in Niger State. Asbestos is used to manufacture asbestos, cement product asphalt and vinyl tiles, insulation gaskets and battery.

(vi) Diatomite:

Diatomite is a sedimentary rock consisting of microscopic siliceous tests of diatoms and rarely of other silica-secreting organisms. It resembles chalk or clay but contains chiefly silica and 3-10 percent water with a little alumina, iron oxides and alkalies. It is also known as diamaceous earth or diamaceous silica. It is used as filter and filler, for heat and sound insulation, for abrasives, in building materials, ceramics and many chemical purposes.

Diatomite deposit occurs in Abakiri and Bularaba in Borno State. The reserve is 10 million tonnes.

G. PRECIOUS METALS:

These include gold, silver and Platinum Group Elements. Although no economic deposit of Silver has yet been found in Nigeria, however, silver all over the world is a common associate of gold. That is wherever gold is found, it is usually accompanied by some silver. The gold deposits of Nigeria should under normal conditions contain some silver.

Gold which finds extensive use as jewellery, ornaments and monetary purposes occurs in many places in Nigeria including Zamfara, Malelemale, in Zamfara State, Minna in Niger State and Itagunmodi and Iperindo in Osun State. The reserves at Itagunmodi are estimated at 6000 troyounces, and those of Ife-Ilesa district at 20000 troyounces. Traces of Platinum have been reported in the platinum quarts reefs associated with the Pan african granites at Kure near Kano.

Platinum is chiefly used in the electrical, chemical and petroleum industries as resistors in telephones, TV, electrodes and radios, coils and X-ray equipment.

H. NON-FERROUS METALS

In Nigeria, deposits of lead-zinc are found in Ririwai, Zuru in Kano State, Wase in Plateau State, Abakaliki, Ohaozara, Ishiagu in Imo State and in Arufu and Ibi in old Gongola State. Lead-zinc deposits are used in the manufacture of storage batteries, electrical cables, ammunitions pipes and as pigments in paints among other uses. Cassiterite (tin ore) occurs in the younger garnites of Northern Nigeria. It is found in Jos, Zaria, Bauchi, Kano, Ijero and Iregun. The reserve of Tin in Jos Palteau is estimated to be 143 million tonnes. Tantalum and Niobium (formerly Columbium) are modern technology rare elements of increasing value because of their metallurgical electronics, chemical and nuclear uses. They are used as high temperature alloys for jet engines, gas turbines and rockets. Important deposits occur at Bauchi with an estimated reserve of 45 million tonnes as well as Kano, Komu, Sepeteri, Lawo-Ile, Egbe, Ijero and Udegi. Bauxite an ore of Alluminium has been reported at Orin-Ekiti, Oyan and Mabila Plateau.

G. FERRO-ALLOY METALS:

These include a group of important metals whose chief use (but not their only use), is for alloying with iron to yield special steels of desired properties. Among these are Manganese, Nickel, Chromium, Molybdenum, Tungsten, Cobalt and Vanadium. Deposits of Manganese have been reported at Tundun Kudu (200,000 tonnes) while there are occurences at Mallam Ayuba both in Kaduna State, Birni Gasari and Gumi in Niger State. Occurences of molybdenum are found in Kigom Hills in Plateau State, Tibchi Hills in Bauchi State and Ikere-Ekiti in Ekiti State. Nickel, Chromium and Cobalt occurences have been found in the schist belts at Mallam Tanko, Kaduna State and Ife-Ilesa in Osun State. Traces of Vanadium have been reported at Abuja. Wolframite, a major ore of Tungsten has been reported to occur as Vein-type deposits and disseminations in griessens associated with Casiterite at Tichi Yeli and Lurei lodes in Kano.

H. GEMSTONES

The Nigerian gemstone occurences have been divided into two major types: the precious and semi-precious stones. The precious stone include: sapphire, ruby of the corrundum group and emeralds and aquamarine of the berryl group. The semi- precious stones include: topaz, garnet, olivine, amethyst, agate, rose quartz, zircon and tourmaline. Known occurences of precious and semi- precious gemstones are found in the Jos Plateau, Keffi in Plateau State, Jem's in Kaduna State, Zaria Dala, Panamadina in Katsina State, Balewa and Hange Hills in Bauchi state. These gemstones have also been are found in Olode, Ofiki, Igbojaiye, Komu and Baba-Ode in Oyo State as well as apomu In Osun State.

From what has been revealed so far, rocks indeed enrich, but they not only enrich us with minerals, these minerals also act as catalysts for modern civilization.

MINERALS CIVILIZE

Today, mineral resources have become almost synonymous with industrial power which in turn, is dependent upon ownership of, or access to, large quantities of mineral resources that have become the backbone of industrial development. Mineral

resources and man are very intimately associated. People emerged from the Stone Age that is, became civilized when they began mining. Yet, they have behaved in the most uncivilized ways because of minerals. Nations and tribes have coveted minerals, stolen them, conspired and fought over them.They still do. In summarizing the relationship between Civilization and minerals, one can say that minerals are difficult to live with and impossible to live without. The search for minerals has given rise to voyages of discovery and settlement of new lands. Their ownership has resulted in industrial development and in commercial and political supremacy.

A look at the history of development of leading industrial nations reveals that their rise had coincided with the development and utilization of their mineral resources. Those nations endowed with diversified mineral resources are the ones that became the great industrial nations and the politically and militarily strong ones. This group is being joined by additional countries based on their petroleum reserves such as the Middle-East countries or by the development of vast mineral resources such as Canada, Australia, Russia and Brazil.

Nations lacking an adequate supply of minerals either became agricultural or aggressive, such as Japan, Germany, Korea, Argentina, and Hong Kong. China and Russia have vast resources of coal and iron ore and are now major industrial Nations. With the vast mineral resources available to Nigeria, it will take some time for her to become an industrial power because of lack of the will and aggression to possess the technology needed to develop her mineral resources.

Few people in this industrial age realize the extent of our dependability upon minerals. In our homes, our stoves, cookers, electric iron, T.V. sets, Satellite dishes, glass doors and windows and all our appliances are made of mineral products. Our various means of transportation such as Cars, Ships, Aircraft, our weapons of war such as Cruise missiles, tanks, machine guns and our communication gadgets such as cell phones, conventional phones, radio, computers for our E-mail and Internet, all require the use of minerals. Minerals indeed civilize.

But can this civilization be sustained at the present rate of supply and consumption of our mineral resources? Studies have shown that the rise of the industrial age has so accelerated the demand for minerals, that the world exploited more of its mineral resources in the period shortly before and after World War 11 than in all the preceding ages. Much of the concern for what will happen to mineral demand and supply in the decades ahead, and I am looking at this from global perspective, is related to the assessment of two conflicting premises. One premise holds that the world population and demand for minerals will skyrocket, while geology, technology, and economic wallow along at their present levels. The result will be imminent and measurable worldwide limits to industrial growth and by extension to civilization. A contradicting premise, aptly labelled the "cornucopian view" by Brooks and Andrews (1974) holds that we can never run out of minerals as long as we have such comforting data as the calculations that each cubic kilometer of average crustal rock contains 200 million tonnes of aluminium, 100 million tonnes of iron, 800,000 tonnes of zinc and so on. Technology is expected to come to our rescue. The view from either extreme is ridiculous.

A few mineral commodities, such as iron and aluminium, for example exist globally in sufficient quantities to maintain the industries of the world and to permit considerable expansion. A few other commodities such as mercury, tin and silver are already pressed to maintain their current production and markets; their prices to consumers are rising and, as a consequence, substitutes are being sought (and not always being found).

Between these two extremes lie the great majority of mineral products. They are present in the earth's crust in amounts sufficient to satisfy current demands and allow for moderate expansion. They cannot however, over a long period of time keep abreast of the rapid increase in world population. This is especially true of the fossil fuels that provide so much of the energy required by our civilization. While some substitution will be possible, general substitution will not be-substitutes cannot fill all our needs of essential minerals. In any case, any substitution must come from the earth's mineral supplies.

From the foregoing, the importance of minerals in the sustaining modern civilization cannot be over-emphasized. However, minerals not only civilise, but they also vitalize.

MINERALS VITALIZE:

Weathering processes break solid rocks into small particles. The most important product of weathering is vegetation-supporting soil. Many soils reflect the composition of the rocks from which they have been derived by weathering. All known natural chemical elements are present in rocks. These elements are released into soils during the chemical weathering of the rocks.

At first thought one might be tempted to assume that there can be little to relate the sciences of Geology and Medicine. However, a few moments of reflection should be enough to permit us to realise that an association between geology and medicine is a natural one. After all, most people are prepared to accept, at least as an hypothesis, the possibility that man's health is determined, to some extent, by the food he eats. The quality of food reflects the make-up of the soil, which in turn is determined, in part, by the chemistry of rocks on the earth's crust.

Certain elements are essential to life and are called vital nutrients. At some concentration, however, each nutrient element can become toxic or even lethal. A substance is said to be toxic if it inhibits the growth or metabolism of an organism when present above certain concentration. All elements are toxic at high concentrations and some are poisons even at low concentrations.

Toxicity may be due to an extremely low concentration of a highly toxic substance or to an unusually high concentration of a slightly toxic or even normally required material. The symptomatic response to toxic materials is acute for high-dosage and chronic for low-dosage, long-time exposure:

Chemical weathering of parent rocks in tropical terrains may lead to the enhancement or depletion of some of the major and trace elements in the residual soils. The total trace element content of a soil may be modified by pedological

processes and the contents of organic matter. Trace and major element contents of soils and underlying rocks are often associated with human disorders.

Kehinde-Phillips et al (2001) have shown in their studies of the distribution of Zinc in the lateritic soils of Ife-Ilesa area, that zinc contents of the soils of Ife-Ilesa area vary from 0.024 mg/g to 0.08 mg/g/ The mean dietary intake of zinc from self-selected diets prepared from food-crops grown on this soil is only 8.4mg/Zn/day compared with the Recommended Dietary Allowance (RDA) of 15mg/Zn/day. Serum zinc levels in the Study area range from 75-77 (ug/d/ (micrograms per deciliter) in women to 78 – 80 (ug/d/ in men compared with normal values of 80 (ug/d/ in women to 88 (ug/d/ in men. Epidemiological Studies in Ife-Ilesa area indicate prevalence of growth retardation, acrodematitis enteropathica and renal malfunction due to this zinc deficiency.

Kehinde-Phillips and Fakoya (2001), have similarly demonstrated that the average concentration of phosphorous in the soils of the same area ranges between 0.09 mg/g to 0.4 mg/g. The global average content of phosphorus in soils is 1.05 mg/g. The recommended dietary allowance of phosphorus is 800 – 1200 mg/d, whereas the average dietary intake of phosphorus from common self-selected diets prepared from food crops grown on these soils is 305 mg/day. These data clearly indicate that the soils of Ife-Ilesa area and food crops cultivated on them are depleted in phosphorus. This deficiency is similarly reflected in the phosphorus content of the fasting blood serum of patients and control subjects which ranges between 2.35 (ug/100ml to 4.50 (ug?100ml as compared to 3.0 (ug/100ml in normal individuals. This phosphorus deficiency has been correlated with prevalence of bone malformation, dental caries and pyorrhea in the study area.

In their study of the concentrations of potassium and magnesium in the soils of Ife-Ilesa area and implications for health, Kehinde-Phillips and Oni (1999), have shown that the recommended dietary allowance of K is 2000 –2500 mg/d, while the mean dietary intake of K from self-selected diets is 1050 mg/d. Similarly, the recommended dietary allowance of Mg is 350-450 mg/d whereas the mean dietary intake of Mg from self-selected diets prepared from food crops grown on these soils is 230 mg/day. These data indicate the deficiency of K and Mg in these soils and this

deficiency has implication for the prevalence of high blood pressure and coronary heart diseases in the study area.

Kehinde-Phillips and Oni (2000) have shown abnormal concentrations of lead in the mechanic villages around Ijebu-Ode. This study indicates that the average dietary intake of lead from diets based on food crops grown on these soils around the mechanic village ranges between 2.5 – 2.8 mg/d compared with a recommended dietary allowance of 0.3 – 0.4 mg/d of Pb. This lead toxicity is reflected in the high serum lead content of patients suffering from hypertension and anaemia in adults and encephalopathy in children.

Kehinde-Phillips and Fakoya (2001) studied the distribution of copper in the lateritic soils developed over the basement complex of Ife-Ilesa and were able to relate the deficiency of copper in the soils to the deficiency in diets and the prevalence of anaemia and malnutrition in infant and Menke's syndrome.

A current study by Kehinde-Phillips et al (in press) has linked toxicity of Aluminium in soils to dialysis, encephalopathy, dialysis osteodystrophy, pakinsonism-dimentia and Alzheimer's disease in the Ife-Ilesa area.

Kehinde-Phillips et al (in press) have shown a high depletion of Calcium in some of the soils of the same area and have correlated this deficiency with breast cancer, high blood pressure and osteoporosis.

My project students have carried out a study of arsenic and Cadmium concentrations in the well-water, streams and rivers in and around Ago-Iwoye. The findings of this study indicate that the W.H.O. permissible limits for arsenic and Cadmium is 0.05 mg/L and 0.01 mg/L respectively, the average contents of both elements in well waters and streams around Ago-Iwoye range from 1.32 – 3.12 mg/L for As and 0.06 – 3.45 mg/L for Cd respectively. The high concentration of these elements is related to the parent rock, the soil agricultural activities as well as sewage sludges along the course of the streams or in their basins of accumulation. Fortunately, as at the time of this study, there were no reported cases of any disease

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associated with these elements. However, it should be pointed out that arsenic and Cadmium are toxic metals which have extremely long biological half life of 15 – 20 years in human. Thus it takes a long time for ingestion of As and Cd before any health hazard manifests. Common diseases associated with the toxicity of arsenic include:

Cardiovascular disorders and that of Cadmium include renal dysfunction.

Similar studies have been done by my project students around Midgal Company in Abeokuta to investigate the high concentrations of Pb and Selenium in the streams and borehole water around the company and relate these to possible disease conditions. Data generated from these studies indicate that the average concentration of Pb in borehole and well waters around Midgal Company is 1.56 mg/l and that of Selenium is 0.14 mg/l. The WHO maximum permissible limits are 0.3 mg/l for lead and 0.03 mg/L for Selenium. These data indicate high toxicity of Pb and Se in the streams and waters around Midgal. Further studies are being undertaken to establish a correlation between these high levels of Pb and Selenium and specific disease conditions.

What makes environmental geochemistry or medical geology such a fascinating subject is that appropriate quantities of such elements as copper, zinc and molybdenum are known to be just as vital to the health of some plants and animals as they are to the success of mining operations; the concentrations of a specific element needed for the fulfillment of these various needs naturally vary considerably. For example, Zinc in appropriate concentrations, is as essential to a diabetic patient as it is for the farmer trying to produce a maximum Kilogramme of pig from each gramme of food and for a forester who is attempting to cultivate a forest. Humans, pigs and trees would all die if no zinc were available and equally, they can all be adversely affected if they are given too much zinc.

For maximum health in both plants and animals, it is desirable not only that the elements should be present in appropriate concentrations but also that there should be harmonious relationships between the conentrations of the different elements. It has taken hundreds of millions of years for life to evolve as we now have it on our planet. Surely, it is reasonable to assume that life today represents a complex

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synthesis of the energy, the environment and the elements present in the Crust of the earth.

CONCLUSIONS

Mr. Vice-Chancellor, let me conclude this lecture by emphasizing that mineral resources are not available in unlimited quantities. Since there are limits to the supplies of minerals that form the basis of a modern industrial civilization, the affluence of our society is in jeopardy. If we are to preserve it, we must answer three questions: How can sufficient quantities of minerals which serve as raw materials for our industries, be obtained over long periods of time? How can the developing nations such as Nigeria, which produce large amounts of the world's minerals be encouraged to develop and improve their standards of living? The future of our affluent civilization depends upon the answers to all three of those questions.

Let me make three recommendations in attempting to solve the problem of mineral shortages in the future.

First, the rate of population growth must be controlled. Without such control, all efforts to improve the lot of peoples in the developing nations and even to maintain the status quo, can at best achieve only temporary and partial success. Shortages of fertilizers and foods, of energy and of mineral products of all kinds are inevitable; poverty and starvation are bound to increase.

Second, every nation must formulate a carefully thought-out and clearly stated mineral policy that is suited to its particular needs and that recognizes the necessity for international co-operation. Such a policy must not be entrusted to an entrenched, unenlightened and arbitrary bureaucracy. Such a policy must be under constant review since the place of minerals in the world economy is seldom static.

Third, the developing nations with abundant mineral resources need help from the industrialized nations to develop the mineral resources which can raise their standards of living. They need foreign capital, technology and personnel to provide the money and the skills required for exploration and for the building and maintenance of mines, mills and smelters. If these developing nations permit foreign capital to earn a fair return, the result will be mutually beneficial. If on the other

hand, they over-tax foreign investment or resort to short-sighted nationalistic measures of expropriation, they will drive away what is most needed – money and trained personnel – to develop their mineral resources and thus their civilization.

Mr. Vice-Chancellor, all the varied inhabitants of the earth, plants and animals alike, are affected by geologic processess and phenomena, but none so much as the group classified as Homo sapiens. We humans cannot escape geology – the study of the earth – even if we wish. We are irrevocably tied to the earth. Thus the individual is created and constrained by the materials of which the earth is made and the various forces and processes that act on it.

Thus, Mr. Vice-Chancellor, Distinguished Guests, ladies and gentlemen, rocks enrich, minerals civilize and vitalize.

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There is somebody I remember with sadness today, my colleague, friend, field companion, foundation staff of the Department of Earth Sciences, Late Dr. S. I. Nurudeen. I know the role you would have played today, if you were here. May your kind soul rest in perfect peace. Amen.

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Mr. Vice-Chancellor, Distinguished Guests, Ladies and Gentlemen, thank you for listening.

Professor O.O. Kehinde-Phillips, MNMGS.
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REFERENCES

Brooks, D. B and Andrews, P. W. (1974): Mineral Resources, Economic Growth and World Population **Science** Vol. 185, No. 4145, pp. 13-19.

Elueze, A. A. (1982b): Mineralogy and Chemical Nature of Meta-ultamafites in Nigerian Schist Belts. **Journal of Mining Geology**, Vol. 19 (2), pp. 21-29.

Kehinde-Phillips, O. O. (1973): Talc Deposists in Apomu, Southwestern Nigeria, 1973. GSN Unpublished Report. 10 pages plus attachments.

Kehinde-Phillips, O. O.; Oni, L. O. A. and Fakoya, E.A.O. (2000): Health Effects from Zn concentrations in soils derived from Basement Complex Rocks of Ife-Ilesa, Southwestern Nigeria. **Tropical Journal of Environmental Research,** Vol. 2, Nos. 1& 2, pp. 21-30.

Kehinde-Phillips, O. O. and Fakoya, E.A.O. (2001): Implications of the variation in Phosphorous contents of soils over mafic rocks in Ife-Ilesa area, Southwestern Nigeria. **Journ. Min. Geol.** Vol. 37, No.2, pp. 211-215.

Kehinde-Phillips, O. O. and Fakoya, E.A.O. (2001): Distribution of Copper in the lateritic soils developed over the basement complex of parts of Southwestern Nigeria and Its Health Implication. **Nigerian Journal of Nutritional Sciences**. Vol. 21, Nos. 1 & 2, pp. 41-44.

Kehinde-Phillips, O. O. and Oni, L.O.A (2001): Pb-concentration i around the Ijebu-Ode Mechanic Village – An Appraisal of L toxicity in Environmental Health **Journal of Pure and Appl Sciences** Vol. 4, No. 2, pp. 5-12.

Kehinde-Phillips, O. O.; Fakoya, E.A.O. and Oni, L.O.A. (In Press). Aluminium concntations of the soils developed over the basement complex rocks of Southwestern Nigeria in relation to human health. **Science Technology.**

Kehinde- Phillips, O.O. ;Oni, L.O.A and Fakoya, E.A.O. (In Press). Concentration of Calcium in the soils over foliated amphibolite and Chlorite quart schist in Ilesa area, Southwestern Nigeria and the implication of Ca-deficiency for human health. **Nigerian Journal of Nutritional Science.**

Kehinde-Phillips, O.O. and Oni, L.O.A. (In Press). Concentration of K and Mg in the soils developed over foliated amphibolite, talc schist, and biotite schist and their effect on environmental health in Ilesa area of Southwestern Nigeria. African Journal of Applied Science.

Kehinde-Phillips, O.O. and Nurudeen, S.I. (1997): Mineral Resources of Sokoto State. Unpublished Sokoto State Government Report. 35p.

Olayemi, G.M.T and Kehinde-Phillips, O.O. (1973): Brick-clay investigation at Tade, Ibadan Southwestern Nigeria. GSN Report No. 1525 & 5p plus attachments.

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