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THE USE OF INNOCUOUS GEO(PHYSICAL) TOOLS IN DISCERNING THE BOWEL OF THE EARTH: A STRATEGY FOR MANPOWER DEVELOPMENT.

By

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PROFESSOR JOSEPH ADENIYI OLOWOFELA
Professor of Solid Earth Geophysics

ACKNOWLEDGMENT

Mr. Vice Chancellor, Sir, permit me to quote Isaac Newton in 1675 "If I have seen further, it is by standing on the shoulders of Giants." Whatever contributions I have made has been made possible by the support and assistance received in life. It is on this account that, I will like to thank all my teachers at Hope Central (Primary) School, Omi-Adio from 1969-1976 and my teachers and colleagues at the United Christian Secondary School, Omi-Adio, Ibadan from 1976-1982. The memory of the pioneer Principal (Mr. Dele Obi) for his astuteness and discipline, lingers on in my mind and memory. University of Ibadan created a turning point in my life. It was there that I cut my teeth on issues of life and all my hidden potential blossomed. I appreciate all my lecturers. I will refrain from mentioning them one by one, so that I do not run into the error of missing some out . I am eternally indebted to Professor Ebun Oni who supervised my projects and theses throughout my University education at Ibadan.

To the current Vice-Chancellor, Prof. Salako, his team of Principal Officers and the Dean, COLPHYS, Professor Mustapha and the entire University staff, I will ever remain grateful for allowing me time to make this presentation.

Let me appreciate my former and current Postgraduate students: Professors Akinyemi, Badmus, Adebayo; Doctors Okeyode, Olurin, Alatise, Alabi (FUNAAB), Doctors Ozebo, Igboama (FUOYE), Olushola (UNILAG), Professor Ogundare, Dr. Adegoke and Dr Titus (U.I), Dr.Ajani (BOWEN) and Dr.Olusola Fasunwon (Canada). Furthermore, I wish to thank Prof. Dr. Peter Borman and the entire Management of Central Institute for Earth Sciences, Potsdam, Germany and Abdul-Salam International Centre for Theoretical Physics, Italy for their support.

I appreciate the immense support of the current Governor of Oyo-State, His Excellency Senator Abiola Ajimobi and the entire cabinet members of Oyo State for providing me the opportunity to showcase the concept of "Town and Gown" as it is preached in the University. I appreciate the editorial team of the university (FUNAAB) and Olamide Agunloye for typesetting the lecture.

I will have no business being here if not for the support of my late parents (Mr. Owen Adeyinka Olowofela and Mrs Ajibike Elizabeth Olowofela (Nee Ajagbe) my brother Biodun Olowofela and my sister Tunrayo Adeoye. My wife Wuraola has been of immense support holding forth the home front in an attempt to excel in my academic pursuit and other endeavors. Let me thank my children for comporting themselves Nike, Seun, Sam, Heritage and Itunu, while I'm out there sacrificing my today so that they can have a better tomorrow.

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The Use of Innocuous Geo (physical) Tools in Discerning the Bowel of the Earth: A strategy for Manpower Development.

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By

PROFESSOR JOSEPH ADENIYI OLOWOFELA

PROTOCOL

The Vice Chancellor,
Deputy Vice Chancellors,
Registrar and other Principal Officers,
Dean School of Post-Graduate Studies
Dean College of Physical Sciences
Deans of Colleges
Directors of Institutes and Units,
Heads of Departments,
Distinguished Guests and Friends,
Great FUNAABITES
Ladies and Gentlemen

Mr. Vice Chancellor Sir, permit me to recount an encounter between Albert Eistein and Charlie Chaplin.

ALBERT EINSTEIN: What I admire most about your art, is its universality. You do not say a word, and yet the world understands you!

CHARLIE CHAPLIN: It's true, but your fame is even greater! The world admires you, when nobody understands you!

Mr. Vice Chancellor, because of plurality of the audience I hope to bridge the gap between these two personalities.

An Inaugural Lecture is an opportunity for newly promoted or appointed Professors to inform colleagues in the University and the general public, about their research career so far and update colleagues on their current and future directions.

FUNAAB INAUGURAL LECTURE SERIES

1.0 Introduction

The Lecture of today has to do with Geophysics, issues determined and relevance to manpower development.

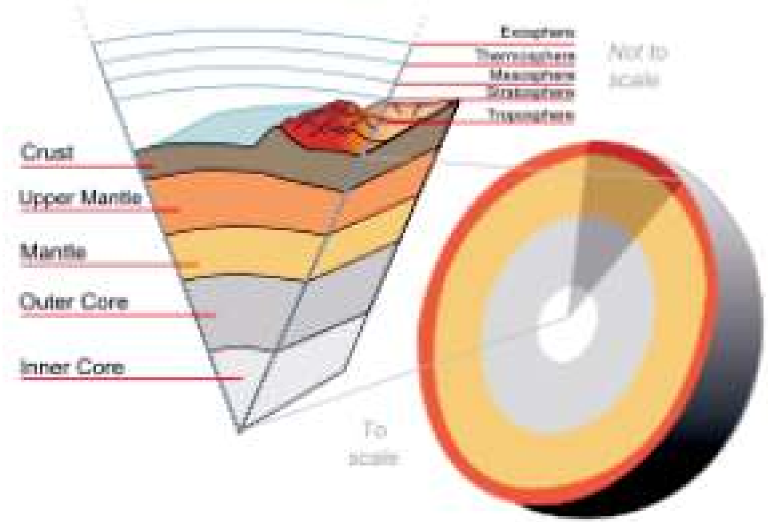


Fig.1: Inner Structure of the earth.

Geophysics is a subject of natural science concerned with the physical processes and physical properties of the Earth and its surrounding space environment, and the use of quantitative methods for their analysis. The term geophysics sometimes refers only to the geological applications: Earth's shape; its gravitational and magnetic fields; its internal structure and composition; its dynamics and their surface expression in plate tectonics, the generation of magmas, volcanism and rock formation. However, modern geophysics organizations use a broader definition that includes the water cycle including, snow and ice; fluid dynamics of the oceans and the atmosphere; and magnetism in the ionosphere and magnetosphere and solar-terrestrial relations; and analogous problems associated with the Moon and other planets.

Geophysics is applied to societal needs, such as mineral resources, mitigation of natural hazards and environmental protection. In Exploration Geophysics, Geophysical survey data are used to analyze potential petroleum reservoirs and mineral deposits, locate groundwater, find archaeological relics, determine the thickness of glaciers and soils, and assess sites for environmental remediation.

1.1 Heat flow

The Earth is cooling, and the resulting heat flow generates the Earth's magnetic field through the geodynamo and plate tectonics through mantle convection. The main sources of heat are the primordial heat and radioactivity, although there are also contributions from phase transitions. Heat is mostly carried to the surface by thermal convection, although there are two thermal boundary layers – the core-mantle boundary and the lithosphere – in which heat is transported by conduction. Some heat is carried up from the bottom of the mantle by mantle plumes. The heat flow at the Earth's surface is about 4.2 × 1013 W, and it is a potential source of geothermal energy.

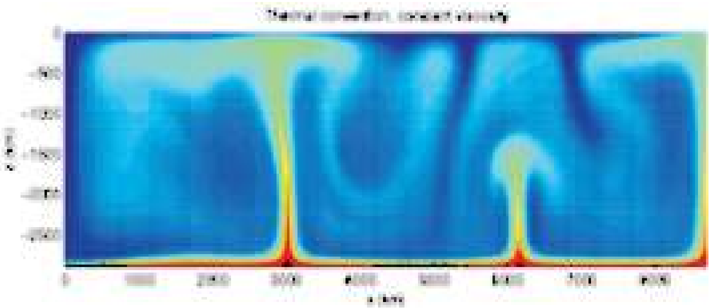


Fig.2: Heat Pattern of the Earth Interior.

1.2 Vibrations

Seismic Waves are vibrations that travel through the Earth's interior or along its surface. The entire Earth can also oscillate in forms that are called normal modes or free oscillations of the Earth. Ground motions from waves or normal modes are measured using seismographs. If the waves come from a localized source such as an earthquake or explosion, measurements at more than one location can be used to locate the source. The locations of earthquakes provide information on plate tectonics and mantle convection.

Measurements of seismic waves are a source of information on the region that the waves travel through. If the density or composition of the rock changes suddenly, some waves are reflected. Reflections can provide information on near-surface structure. Changes in the travel direction, called refraction, can be used to infer the deep structure of the Earth.
Earthquakes pose a risk to humans. Understanding their mechanisms, which depend on the type of earthquake (e.g., intraplate or deep focus), can lead to better estimates of earthquake risk and improvements in earthquake engineering

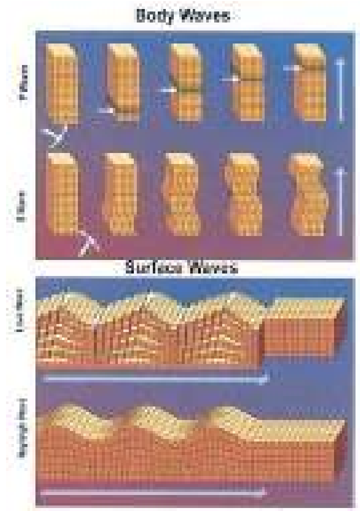


Fig.3: Pattern of Seismic wave propagation

1.3 Gravity Geophysical Method

The gravity field on the surface of the Earth is not uniformly the same everywhere. It varies with the distribution of the mass materials below. This lateral change can be measured and interpreted in terms of likely causative geology. A Gravity survey is an indirect (surface) means of calculating the density property of subsurface materials. The higher the gravity values, the denser the rock beneath.

1.3.1Properties

Gravitation is the force of attraction between two bodies, your own and the Earth for example. The strength of this attraction depends on the mass of the two bodies and the distance between them. A mass falls to the ground with increasing velocity. The rate of increase is called gravitational acceleration or g for gravity. The unit of gravity is the Gal (in honor of Galileo). One Gal equals 1 cm/sec2.

Various rock types within a study area often contrast enough in density to cause gravity anomalies. The specific gravity of earth materials varies from 1.2–1.5 for unconsolidated alluvium; 2.5–3.5 for hard igneous or metamorphic rocks; to 3–5 for massive metallic minerals. A void has a density of zero, but if filled with water or mud, the density will be about 1–1.5. The specific gravity of water is 1.0.

Specialized gravity meters are used to measure the effects that comprise the Earth's gravity field. For near-surface investigations, the working surface on which the measurement is made is also important. The elevation of the measurement point must be known, or first determined, to better than 2 centimeters.

Crew size is usually small. However, much effort is spent in measuring the elevations to the required precision. Thus several persons may be required during much of the field work.

The gravity geophysical survey method involves making several mathematical corrections to the measured data to correct for: the

elevation of the measurement point, the spatial location of the instrument with respect to the earth, the density of the surface material, the tides, and the surrounding topography, all of which require expertise and specialized processing of the gravity data.

Overly optimistic impressions about the precision of the reading (some manufacturers sell instruments with a one microgal graduation on its dial) and the size of the expected response from the target, are potential misunderstandings in the use of the gravity method.

Plan maps of station locations, contour maps of reduced gravity values, residual-anomaly separation maps, final anomaly maps, and an inversion of the anomaly values (based on an assumed or measured density contrast) to a causative geologic body.

1.4 Magnetic Survey

Magnetic survey, one of the tools used by exploration geophysicists in their search for mineral-bearing ore bodies or even oil-bearing sedimentary structures and by archaeologists to locate and map the remains of buried structures. The essential feature is the measurement of the magnetic-field intensity and sometimes the magnetic inclination, or dip, and declination (departure from geographic north) at several stations. If the object of the survey is to make a rapid reconnaissance of an area, a magnetic-intensity profile is made only over the target area. If the object of the survey is to delineate already discovered structures, the surveyor sets up a grid over the area and makes measurements at each station on the grid. The corrected data is then entered on a scale drawing of the grid, and contour lines are drawn between points of equal intensity to give a magnetic map of the target area that may clearly indicate the size and extent of the anomalous body. (Encyclopaedia Britannica)

1.5 Electricity

Although we mainly notice electricity during thunderstorms, there is always a downward electric field near the surface that averages 120 volts per meter. Relative to the solid Earth, the atmosphere has a net positive charge due to bombardment by cosmic rays. A current of about 1800 amperes flows in the global circuit. It flows downward from the ionosphere over most of the Earth and back upwards through thunderstorms. The flow is manifested by lightning below the clouds and sprites above.

A variety of electric methods are used in geophysical survey. Some measure spontaneous potential, a potential that arises in the ground because of man-made or natural disturbances. Telluric currents flow in Earth and the oceans. They have two causes: electromagnetic induction by the time-varying, external-origin geomagnetic field and motion of conducting bodies (such as seawater) across the Earth's permanent magnetic field. The distribution of telluric current density can be used to detect variations in electrical resistivity of underground structures. Geophysicists can also provide electric current themselves.

Electromagnetism occur in the ionosphere and magnetosphere as well as the Earth's outer core. Dawn chorus is believed to be caused by high-energy electrons that get caught in the Van Allen radiation belt. Whistlers are produced by lightning strikes. Hiss may be generated by both. Electromagnetic waves may also be generated by earthquakes (see seismo-electromagnetics).

In the Earth's outer core, electric currents in the highly conductive liquid iron create magnetic fields by electromagnetic induction (see geodynamo). Alfvén waves are magnetohydrodynamic waves in the magnetosphere or the Earth's core. In the core, they probably have little

observable effect on the geomagnetic field, but slower waves such as magnetic Rossby waves may be one source of geomagnetic secular variation.[16]

Electromagnetic methods that are used for geophysical survey include transient electromagnetics and magnetotellurics.

1.6 Magnetism

The Earth's magnetic field protects the Earth from the deadly solar wind and has long been used for navigation. It originates in the fluid motions of the Earth's outer core (see geodynamo). The magnetic field in the upper atmosphere gives rise to the auroras.

The Earth's field is roughly like a tilted dipole, but it changes over time (a phenomenon called geomagnetic secular variation). Mostly the geomagnetic pole stays near the geographic pole, but at random intervals averaging 440,000 to a million years or so, the polarity of the Earth's field reverses. These geomagnetic reversals, analyzed within a Geomagnetic Polarity Time Scale, contain 184 polarity intervals in the last 83 million years, with change in frequency over time, with the most recent brief complete reversal of the Laschamp event occurring 41,000 years ago during the last glacial period. Geologists observed geomagnetic reversal recorded in volcanic rocks, through magnetostratigraphy correlation (see natural remanent magnetization) and their signature can be seen as parallel linear magnetic anomaly stripes on the seafloor. These stripes provide quantitative information on seafloor spreading, a part of plate tectonics. They are the basis of magnetostratigraphy, which correlates magnetic reversals with other stratigraphies to construct geologic time scales. In addition, the magnetization in rocks can be used to measure the motion of continents.

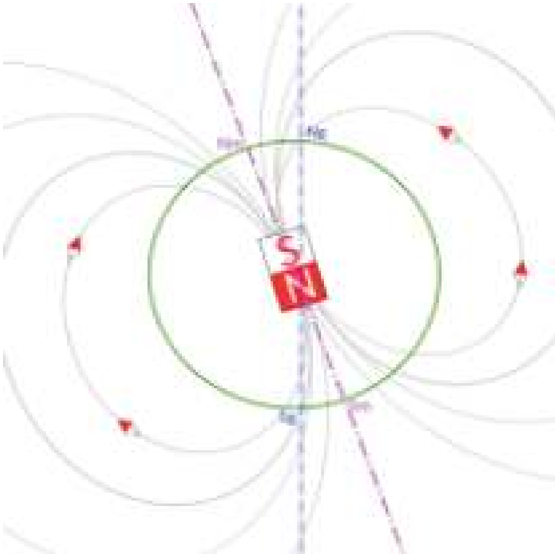


Fig.4 Earth's dipole axis (pink line) is tilted away from the rotational axis (blue line).

1.7 Radioactive decay

Radioactive Decay accounts for about 80% of the Earth's internal heat, powering the geodynamoand plate tectonics. The main heat–producing isotopes are potassium–40, uranium–238, uranium–235, and thorium–232. Radioactive elements are used for radiometric dating, the primary method for establishing an absolute time scale in geochronology. Unstable decay at predictable rates, and the decay rates of different isotopes cover several orders of magnitude, so radioactive decay can be used to accurately date both recent events and events in past geologic eras. Radiometric mapping using ground and airborne gamma spectrometry can be used to map the concentration

and distribution of radioisotopes near the Earth's surface, which is useful for mapping lithology and alteration.

1.8 Geophysical fluid dynamics

Fluid Motion occur in the magnetosphere, atmosphere, ocean, mantle and core. Even the mantle, though it has an enormous viscosity, flows like a fluid over long time intervals (see geodynamics). This flow is reflected in phenomena such as isostasy, post–glacial reboundand mantle plumes. The mantle flow drives plate tectonics and the flow in the Earth's core drives the geodynamo.

Geophysical fluid dynamics is a primary tool in physical oceanography and meteorology. The rotation of the Earth has profound effects on the Earth's fluid dynamics, often due to the Coriolis effect. In the atmosphere it gives rise to large–scale patterns like Rossby waves and determines the basic circulation patterns of storms. In the ocean they drive large–scale circulation patterns as well as Kelvin waves and Ekman spirals at the ocean surface. In the Earth's core, the circulation of the molten iron is structured by Taylor columns.

Waves and other phenomena in the magnetosphere can be modeled using magnetohydrodynamics.

Water is a very complex substance and its unique properties are essential for life. Its physical properties shape the hydrosphere and are an essential part of the water cycle and climate. Its thermodynamic properties determine evaporation and the thermal gradient in the atmosphere. The many types of precipitation involve a complex mixture of processes such as coalescence, supercooling and supersaturation. Some precipitated water becomes groundwater, and groundwater flow includes phenomena such as percolation, while the conductivity of water makes electrical and electromagnetic methods useful for tracking groundwater flow. Physical properties of water such as salinity have a large effect on its motion in the oceans.

1.9 Mineral Physics

Mineral Physics The physical properties of minerals must be understood to infer the composition of the Earth's interior from seismology, the geothermal gradient and other sources of information. Mineral physicists study the elastic properties of minerals; their high-pressure phase diagrams, melting points and equations of state at high pressure; and the rheological properties of rocks, or their ability to flow. Deformation of rocks by creep make flow possible, although over short times the rocks are brittle. The viscosity of rocks is affected by temperature and pressure, and in turn determines the rates at which tectonic plates move (see geodynamics).

Table 1: In solid Earth Geophysics, the table below gives a summary of Geophysical Surveying Methods

Number	Method	Measured Parameters	Physical Property
1	Seismic	Travel time of reflected and refracted seismic waves.	Density and elastic moduli, which determine the velocity of seismic waves.
2	Gravity	Spatial variations of the gravitational field of the earth.	Density of the earth materials.
3.	Magnetic	Spatial variations in the strength of the geomagnetic field of the earth	Magnetic Susceptibility and remanence
4.	Electrical		
	Resistivity	Earth Resistance	Electrical conductivity
	Induced polarization	Polarization voltages or frequency dependents ground resistance.	Electrical capacitance
	Self-Potential	Electrical Potentials	Electrical Conductivty
5.	Electromagnetic	Response to the electromagnetic field	Electrical conductivity and inductance
6.	Radar	Travel times of reflected pu lse	Dielectric constant
7.	Radiation	Activity Concentrations	Radionuclides

2.0. Research Tools

In order to investigate the earths, tools are required. Knowledge of the interior came from many studies, especially from earthquake studies.

In my research the tools applied are :

(i) Mathematical tools
(ii) Modelling
(iii) Instrumentation and Control
(iv) Computational
(v) Radiation

These tools have assisted me in my research endeavors and most of them are innocuous.

In my research efforts of studying Geophysics, I have cause to study the following: Resistivity technique, Magneto-telluric, Seismic, Magnetics, Gravity, Tomography, Porous media, Heat-flow, Aero-magnetism and Radiation.

Mr. Vice Chancellor, Sir, I have laid a general background for the lecture; however we shall go into specifics now:

2.1 RESISTIVITY

What is the electrical conductivity of the Earth This question, though of much interest to geophysicists, physicists and geologists, is misphrased. This is because zones of homogeneity exist within the Earth and it would be wrong to try and measure the conductivity of several layers of the Earth. The Earth could be said to contain several unconsolidated and consolidated layers being the weathered layers. Below this layer are several consolidated unweathered layers. An accurate answer to the above question will assist in unravelling the types, quantity, quality and positions of minerals below the Earth's surface.

The point of contact between physics and geology has shown that the Earth's conductivity is a key to its interaction with both terrestrial and extraterrestrial electric and magnetic elds. Because its primary constituents are insulating silicon oxide (SiO2), one might think that the crust is a poor conductor of electricity. However, large quantities of surface and underground water put the Earth's outer electrical conductivity within a few orders of magnitude Electrical prospecting is far more diversied than other geophysical methods. Electrical methods are much more frequently used in searching for metals and minerals.

However, a method such as the resistivity method in which currents are introduced into the Earth, is called an articial method. Electrical prospecting methods are being employed to an increasing extent in engineering geology, where resistivity measurements are used for nding the depth to bedrock and also in geothermal exploration. All resistivity techniques, in general, require the measurement of apparent resistivity .

The industrial equipment for this work is called the Terrameter. It is an instrument that although it measures the supplied current and potential difference across the two potential probes, has now undergone a lot of changes. It now has a logic unit which converts the measured current and potential difference into resistance. Basically, any geoelectric equipment consists of two parts: the 'power unit' and the 'measuring unit'. A simple instrument was fabricated adapting the experimental set-up of Avants et al using commonly available physics laboratory devices . The choice of various components is from personal initiative and this may also be duplicated in any standard

physics laboratory. The experimental set-up was designed and constructed and this is used for the experiment (figure 5). The lock-in amplifier is used to detect a phase difference between the output signal from the ground and the input signal to the ground. This was constructed using two
10 k resistors connected in input and forward bias through a 741 operational amplifier can vary the current. The signal generator was constructed using operational amplifiers. All the operational amplifiers used are the LM-741 range with a maximum voltage input 25 V. The typical output impedance for the LM-741 is 75. The sine/square wave generator was used as our generator. We choose our components so that the signal can be adjusted between frequency 25 and 650 Hz. However our output is taken from the sine wave Voutput and not the square wave output. This is so because a square wave is made up of a fundamental square wave and its infinite harmonics. The output of the fundamental square wave reduces.

This led to the publication in European Journal of Physics:

Measuring the electrical resistivity of the Earth using a fabricated resistivity
Meter: J.A.Olowofela, V.O. Jolaosho and B.S. Badmus 2005

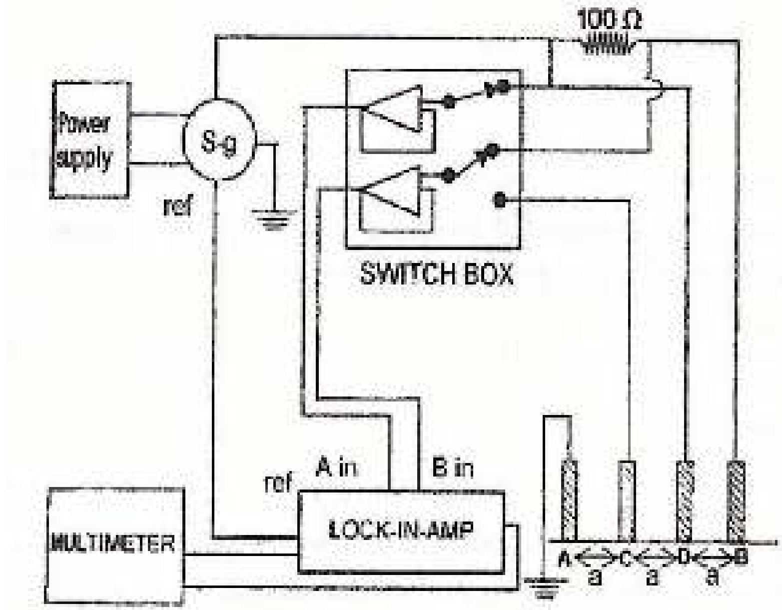


Fig.5Circuit Diagram of the Fabricated Resistivity Meter.

Subsequently, we have used the standard Terrameter for varous studies, which include finding aquifer level (searching for water) delineation of Foundation and environmental determination of an area.

Geo-electric Investigation of the proposed seismographic station at the University Ibadan, Ibadan, Nigeria. J.A.Olowofela, B.S.Badmus and C.Offor 2004

Current variation in electrical resistivity probing using Wenner and Schlumberger arrays in a basement terrain. Badmus B.S. Ayolabi E.A. Olowofela J.A. Adisa J.A. and Oyekunle T.O. 2005.

Mapping of unconfined aquifer using vertical electrical sounding (VES) at Lagos State University (Lasu), Ojo A.S.Ogungbe, J.A.Olowofela,O.O.Oresanya and A.A.Alabi 2010.

Subsurface Characterization using Electrical Resistivity(Dipole-Dipole) method at Lagos State University (LASU) Foundation School, Badagry. J.A.Ogungbe, J.A.Olowofela, O.J.Da-Silva, Alabi A.A and E.O.Onari 2010. Z

2.1 Electrical Resistivity Tomography

Electrical resistivity tomography (ERT) or electrical resistivity imaging (ERI) is a geophysical technique for imaging sub-surface structures from electrical resistivity measurements made at the surface, or by electrodes in one or more boreholes. If the electrodes are suspended in the boreholes, deeper sections can be investigated. It is closely related to the medical imaging technique electrical impedance tomography (EIT), and mathematically is the same inverse problem. In contrast to medical EIT, however, ERT is essentially a direct current method.

Electrical impedance tomography (EIT) is a noninvasive type of medical imaging in which the electrical conductivity, permittivity, and impedance of a part of the body is inferred from surface electrode measurements and used to form a tomographic image of that part. Electrical conductivity varies considerably among various biological tissues (absolute EIT) or the movement of fluids and gases within tissues (difference EIT). The majority of EIT systems apply small alternating currents at a single frequency, however, some EIT systems use multiple frequencies to better differentiate between normal and suspected abnormal tissue within the same organ (multifrequency-EIT or electrical impedance spectroscopy).
A technique similar to EIT is used in geophysics and industrial process monitoring – electrical resistivity tomography. In analogy to EIT, surface electrodes are being placed on the earth, within bore holes, or within a

vessel or pipe in order to locate resistivity anomalies or monitor mixtures of conductive fluids.[14] Setup and reconstruction techniques are comparable to EIT. In geophysics, dates back to 1930s

Application of Electrical Impedance Tomography (EIT) in the Investigation of the Impact of Solid Waste. J.A.Olowofela, O.D.Akinyemi and A.S.Ogungbe 2012.

3D Electrical Resistivity Tomography (ERT) Survey of a Typical Basement Complex Terrain. B.S.Badmus, O.D. Akinyemi, J.A.Olowofela and G.M.Folarin 2011.

3.0 Temperature-dependent thermal diffusivity

Knowledge of thermal properties of the materials that constitutes the interior of the earth is indispensable in understanding the thermal structure of the earth (Horai,1977).
Shabbir et al 2000 is of the opinion that to understand the thermal structure of rocks, investigation of thermo physical properties, which characterize their capacity to accumulate and conduct heat, and the changes that take place under the action of heat, is very important.
Geothermal phenomenon which is within the reach of drilling and mining are of practical importance.
The absorption of heat by rocks is always accompanied with a rise in the kinetic energy of their vibrating molecules and atoms, and is recorded as a change of temperature. The frequency and the amplitude of molecular and atomic vibration increases with the rise of temperature and there is a direct relation between the quantity of heat absorbed q and the temperature of rocks.
From the first law of thermodynamics, $dQ = dQ1 + dQ2$
Where $dQ1$ = part of the heat transformed into the internal energy of the body heated.
$dQ2$ = part of the heat spent on external work (thermal expansion,

polymorphic transformation, etc.)
Hence, $dQ1 = CdT$
Where C is the molecular (or molar) heat capacity at constant volume.
The molar heat capacity C divided by the unit mass of the material heated is known as the specific heat of rocks c: $c = C/m$
The second type of thermal conduction can be identified with the special form of elastic vibrations of the particles of a crystal lattice, heat conduction by lattice vibrations is called phonon, which has energy equivalent to hf (like photon) where h is Planck's constant and f the frequency of elastic vibration in hertz.
If we consider an isolated rock specimen of rectangular shape with temperatures T1 and T2 on opposite faces (T1>T2) then the amount of heat dQ transferred from one face to the other through an area

Δs in time dt is $dQ = K\frac{\Delta T \Delta S dt}{\Delta x}$ Where K is the thermal conductivity of the specimen.

□T = T1 – T2 = temperature between the faces.

□x = distance between them.

The parameter $\frac{dQ}{\Delta S dt}$ =q is the specific heat flow and indicates the heat flowing through an area □S in unit time.

Thermal conductivity of rocks K is the quantity of heat passing through a unit area in a unit time at unit temperature gradient:

$K = \frac{dQ \Delta S}{dt \Delta S \Delta T} = \frac{q}{\Delta T}$ J/ms°C or □°C

$$K = \frac{1}{3} C_v V \partial l$$

Where Cv = heat capacity at constant volume, v = mean velocity of elastic waves in the specimen
l= mean free path of phonons

∂ = pressure coefficient of thermal conductivity

The last quantity is the factor that hampers fast propagation of heat in rocks.

3.1 Thermal diffusivity

The penetration of temperature changes into a solid body depends upon the thermal diffusivity of the material. Good thermal diffusivity allows fast and deep penetration of heat.
Thermal diffusivity, $\alpha = K/\rho c$ (cm^2/s)
We carried out some investigations of thermo-physical materials which include but not limited to:
Spatio-temporal variability and fractal characterization of the thermal conductivity measured in situ in a natural clay soil. Akiyemi O.D., Olowofela J.A., Sauer T.J. and Fasunwon O.O. 2004.
Effect of probe material on the measurement of thermal conductivity of soils
Akinyemi O.D., Olowofela J.A. and Akinwale O.O. 2004.
Transient Method of determining thermal diffusivity and thermal conductivity of basalt. Olowofela J.A. and Fasunwon O. 2005.
Thermal conductivity of soil with heavy metals concentration from the Niger Delta region of Nigeria. Akinyemi O.D.,Olowofela J.A., Akinlade O.O. and Akande O.O. 2006
Determination of conductivity of rock samples using fabricated equipment. O.O.Fasunwon J.A.Olowofela., O.O. Ocan, O.D. Akinyemi 2005

Effect of Depth on thermal signature of buried metallic object. J.A.Olowofela, O.D. Akinyemi.,R.Bello and A.A. Alabi 2010.
Temporal variation of ground temperature at depths 2cm to 200cm in an experimental field in Abeokuta, South-Western Nigeria. A.A.Alabi, O.D. Akinyemi, J.A. Olowofela, F.K.Salako, G.A.Ajiboye and O.T.Olurin 2017.

4.0 MAGNETICS

Magnetic field strengths are usually measured in nanoTesla (nT). The magnetization of a solid body is defined by its magnetic moment per unit volume and is a vector, having direction as well as magnitude.
Susceptibility
A body placed in a magnetic field acquires a magnetization which, if small is proportional to the field: $M = kH$
The susceptibility, k, is very small for most natural materials, and may be either Negative (diamagnetism) or positive (paramagnetism). The fields produced by dia–and paramagnetic materials are usually considered to be too small to affect survey magnetometers, but modern high–sensitivity mag–netometers are creating exceptions to this rule. Most observed magnetic anomalies are due to the small number of ferro– or ferri–magnetic substances in which the molecular magnets all of which have Curie temperatures of about 600°C, are the only important naturally occurring magnetic minerals and, of the three, magnetite is by far the most common. Hematite, the most are held parallel by intermolecular exchange forces. Below the Curie temperature, these forces are strong enough to over–come magnetite the effects of thermal agitation. Magnetite, pyrhotite and Quoted susceptibilities are for Earth–average field
The magnetic properties of highly magnetic rocks tend to be extremely variable and their magnetization is not strictly proportional to the applied field.

In our studies of magnetics, we worked on the following:
Isolation of residuals using trend surface analysis to magnetic data. Olowofela J.A.,Igboama W.N., Adelusi O.A and Ugwu N.U,2006.
Ground-Magnetic study of Ijapo area of Akure, Ondo State, Nigeria . Fasunwon O.O., J.A.Olowofela. O.D. Akinyemi and A. Asunbo 2006.
2-Dimensional Spectra Analysis of Magnetic Anomalies of South eastern Part of middle-Niger Basin, Central Nigeria. Sunmonu L.A., Adabanija S.,and Olowofela J.A.2000.
Computation of geomagnetic Elements for Nigeria for the Year 2000 and 2010. Olowofela J.A., Salawu O.R. and Akinlade O.O. 2004.

4.1 Aeromagnetic Studies

Our current research work is also on aeromagnetic studies.

In aeromagnetic surveys, magnetic measurements are made from low–flying airplanes flying along closely spaced, parallel flight lines. This is a common type of geophysical survey carried out using a magnetometer aboard or towed behind the aircraft. The principle is similar to a magnetic survey carried out with a hand–held magnetometer, but allows much larger areas of the Earth's surface to be covered quickly for regional reconnaissance. The aircraft typically flies in a grid–like pattern with height and line spacing determining the resolution of the data (and cost of the survey per unit area). Additional flight lines are flown in a direction perpendicular to the main transect to assist in data processing. As the aircraft flies during a survey, the magnetometer records tiny variations in the intensity of the ambient field which is the sum total of the earth's field (with its regional variations), the local effects of magnetic minerals in the crust, as also the temporal effects due to the constantly varying solar wind. By subtracting the solar and regional effects, the resulting aeromagnetic map shows the spatial distribution and relative abundance of magnetic minerals (most commonly the iron oxide mineral magnetite) in the upper levels of the crust. The huge volumes of data acquired through aeromagnetic surveys are processed into a digital aeromagnetic map.

Because different rock types differ in their content of magnetic minerals, aeromagnetic maps allow a visualization of the geological structure of the upper crust in the subsurface, particularly the spatial geometry of lithounits and the presence of folds and faults. Aeromagnetic surveys are particularly useful where bedrock is obscured by surface regolith, soil or water. Aeromagnetic data was once presented as contour plots, but now is more commonly expressed as colored and shaded computer generated pseudo-topography images. The apparent hills, ridges and valleys are referred to as aeromagnetic anomalies. A geophysicist can use mathematical modeling to infer the shape, depth and other properties of lithounits responsible for the anomalies.

Aeromagnetic surveys are widely used to aid in the production of geological maps and are also commonly used in mineral exploration. Some mineral deposits are associated with an increase in the abundance of magnetic minerals, and occasionally the sought after commodity may itself be magnetic (e.g. iron ore deposits). The data from aeromagnetic surveys are processed and plotted at a map scale that will allow the flight lines to be properly discriminated. At 1:50,000 scale, for example, a flight-line spacing of I km is satisfactorily represented by 2 cm on the map. The final maps are often reduced to 1:100,000 or 1:250,000 for matching with regional topographic and geologic maps.

Aeromagnetic anomalies so slight that they rise to only a few gammas (gamma 10-1 gauss) above the regional background may be significant in a mapping program. In a more direct connotation, magnetic anomalies may rise to 10,000 or 50,000 gammas over an iron orebody. Among the most common magnetic minerals, magnetite, ilmenite, pyrrhotite, and specular hematite, magnetite has by far the highest magnetic susceptibility and is the most common accessory rock mineral. A strong

aeromagnetic anomaly may therefore be associated with a variety of rock conditions, such as a tactite zone or a magnetite-rich mafic intrusion or volcanic flow bordered by felsic intrusions, by rhyolitic volcanics, or by most kinds of sedimentary rocks. Some sedimentary rocks, such as ferruginous shale and "ironstone," will of course show a magnetic response. Metamorphic derivatives of ferruginous sedimentary rocks cause some of the strongest magnetic responses. Precambrian banded iron formations have a particularly high magnetic susceptibility.

Aeromagnetic anomalies are best interpreted by incorporating geologic mapping and other geophysical information (gravity, seismic-reflection) where available. Interpretations often involve both map-based information (e.g., a fault map) and three-dimensional information (e.g., a geologic cross section). Revelation of subsurface structure of the upper crust is perhaps the most valuable contribution of aeromagnetic surveys.

4.2 Airborne Geophysical Survey Program (Nigeria Geological Survey Agency of Nigeria)

The need to re-invigorate the solid minerals sector necessitated Federal Government of Nigeria to embark on the provision of quality geosciences data through an airborne geophysical survey programme. Contract was awarded to Fugro Airborne Surveys (Fugro) to carry out the survey over the areas designated Blocks A & C and B in the “Phase I” programme. This was after their successful execution of the Ogun State Pilot Project in 2003. This exercise represented 44% national coverage. The project was carried out under the supervision of the Nigerian Geological Survey Agency (NGSA), a parastatal of the Ministry of Mines and Steel Development.

Following the success achieved in the Phase 1 programme, the World Bank, through the Sustainable Management of Mineral Resources Project (SMMRP) Nigeria also commissioned Fugro Airborne Surveys

(Fugro) to conduct the Phase II airborne survey, representing the remaining 55% coverage of Nigeria's landmass.
These data collected in the two phases were in the magnetic, radiometric, gravity and electromagnetic domain. The surveys were mostly flown at 500 m line spacing and 80 m mean terrain clearance generating a total of about 2 million line-km data.

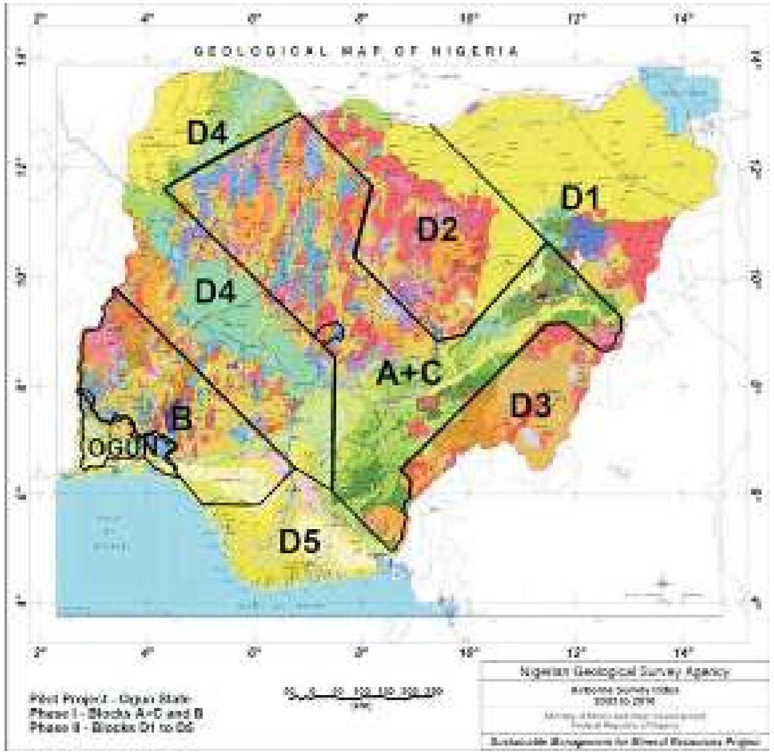


Fig.6 : Aeromagnetic Map of Nigeria (Courtesy: Nigeria Geological Survey of Nigeria)

Mr. Vice Chancellor, I will like to report that the Department of Physics, FUNAAB is one of the active research centres on Aeromagnetic studies in Nigeria.

We have published and unpublished works in this regard, an example of which is an unpublished Ph.D. thesis – Determination of Magnetic Mineral Potentials using Airborne Magnetic Data for Ogun State and its Environs, Southwestern Nigeria (Olurin Ph.D. 2014).

Depth Estimation and Source Location of Magnetic Anomalies from a Basement Complex Formation, Using Local Wavenumber Method. J.A.Olowofela, O.D.Akinyemi, B.S.Badmus, M.O.Awoyemi, O.T.Olurin and S.A.Ganiyu 2013

Source Location and Depth Estimation from Digitised Aeromagnetic Data Acquired from Basement Complex Formation. J.A.Olowofela, B.S.Badmus, G.A. Ganiyu, O.T.Olurin and P.Babatunde. 2011

Mr. Vice Chancellor sir, let me quickly reiterate that other areas of research which we are working on include
Electromagnetic and Magneto-telluric research with respect to earth physics. This culminated in the following publications:

Magne-totelluric response on vertically inhomogeneous earth with homogeneous transition medium. Olowofela J.A., 2004.
Electromagnetic modeling with wave tilt and reflection coefficient: an application to stratified earth media. Olowofela and Ozebo 2006.

5.0 Porous Media.

The concepts of porous media have attracted a great deal of attention in recent years. The application covers a variety of fields, from physics to geophysics, engineering, soil mechanics and underwater acoustics. In particular, in the exploration of oil and gas reservoirs, it is important to predict the preferential directions of the fluid flow.

Modelling effective rheologies for viscoelastic porous media with application
to silt, and medium and coarse sand. Olowofela J.A. and Adegoke J.A. 2004

The wave propagation properties of synthetic porous media such as sintered glass beads were successfully described by Biot's theory of dynamic poroelasticity (Biot 1962). Discrepancies between Biot's theory and measurement are due to complex pore shapes, which are not present in simple synthetic media or in natural porous media such as sandstone (Gist 1994). This complexity gives rise to a variety of matrix–uid interactions which contribute to the attenuation of different wave modes. Different matrix–uid attenuation mechanisms are introduced into Biot's theory by substituting the uid–solid coupling modulus with a time–dependent relaxation function based on the standard linear solid mode. The introduction of memory variables for avoiding the time convolutions yields a set of rst-order differential equations for dynamic poroviscoelasticity (Carcione 1998).

According to Gurevich (1996) the value of poroelastic wave modelling is unclear without comparing its results to the corresponding simulation based on single-phase modelling. This is particularly important in the seismic range where poroelastic effects are relatively small. However, Gurevich and Lapotnikov (1995) have shown that attenuation levels and velocity-dispersion measurements can be explained by the combined effects and energy transfer between wave models.

This work compares the attenuation and phase velocities in different media (silt, medium and coarse sand) which largely depend on their composite densities. The objective of this work is to verify the effect of porosity of media vis-à-vis their composite densities on the phasea velocities and the attenuation of waves, laying emphasis on silt, and medium and coarse sand. The result of the work done by Carcione (1998) was used as a reference in the application to different media.

The results enable us to compare the attenuation and velocities of waves in these media. We observed that the density of coarse sand is greater than that of medium sand and this in turn is greater than that of silt—the same holds for the velocities of P-waves in these media but the situation is converse for shear waves in the same given media. As the densities of the media increase, their attenuation decreases as it was found that the attenuation of silt is the highest and that of coarse sand lowest for the media considered.

We equally worked on:
Effects of clay content and porosity on wave velocities in unconsolidated media using empirical relations. Olowofela J.A., Kamiyole I.C., and Adegoke J.A. 2004
Most igneous rocks are metamorphic rocks have little or no porosity and velocities of seismic waves in such rocks depend mainly on the elastic properties of their constituents minerals. In general, velocities of seismic waves in igneous rocks show a narrower range of variation than those in sedimentary or metamorphic rocks. The average velocity in igneous rocks is higher than that in other types of rocks. The rock with the highest velocities is dunite –an ultrabasic rock that some believe is an important constituent of the earth's mantle. Most metamorphic rocks show an even wider range of variation in velocities, e.g., in gneiss, velocities range from 3536 to 7559 m/s. Sedimentary rocks generally exhibit a much

greater per cent increase in velocity with increasing pressure.
Seismic velocities are quite different in different sedimentary rocks. These rocks show little variation in speed even for different depths of burial. The highest reported velocity in sedimentary rocks is about 7620m/s in a dolomitic limestone.
In our research efforts we determined new (empirical relations) for wave velocities which take into account clay content and porosity
The relations are:

$Vp = 5.57 - 6.47\phi - 2.27C^{1-\phi}$

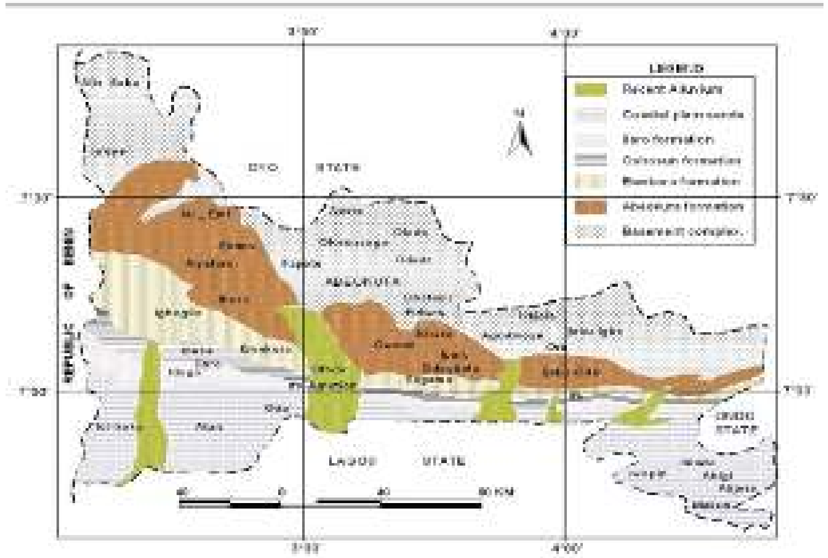
$Vs = 3.41 - 4.44\phi - 2.23C^{1-\phi}$

These have been used to compute velocities for various porosities and clay contents. Which have also been experimentally proven to be valid.

In our effort to understand further the concept of porous media, we conducted a research on
Experimental investigation of factors affecting compressional and shear wave velocities in shale and limestone of Ewekoro formation of Southern Nigeria sedimentary basin. Olurin et.al., 2008

Compressional Vp and shear Vs velocities measurements were taken out on fluid-saturated shale and limestone obtained from the Ewekoro quarry of Southern Nigeria sedimentary basin at constant differential pressure of 50 MPa with porosities ranging from 0.32 to 0.53% and 0.01 to 0.35 for limestone and shale, respectively, while the volume of clay content C ranges from 0 to 60% and 0 to 40% for limestone and shale, respectively. Correlation coefficient for the velocities of both clean samples and those with clay minerals ranged from 0.972 to 1.000 and 0.971 to 1.000, respectively, with limestone having the lesser for both. A very small amount of clay, about 0.21 and 0.23, reduced the elastic modulus of limestone and shale, respectively. For water-saturated shaly samples, Vs was more sensitive to porosity and clay content than Vp. Consequently,

velocity ratios Vp/Vs also showed a reason-able degree of correlations with clay content and porosity. For both limestone and shale studied, the presence of porosity is the most important parameter in reducing velocities followed by clay content due to the softening of functions of porosity and clay content of porous shale and limestone of Ewekoro formations



\Fig.7 Geological Map of Ogun State

The following conclusions can be drawn, with the limitation of the experimental procedure, from the experimental results.
The compressional Vp and shear wave Vs velocities obtained for all the limestone and shale were incorpo-rated into time average equation and linear relation models that contain clay content term and these improve the results for both Vp and Vs.The results obtained from both models for all the clean limestone and shale show the inadequacies of these models

by overestimating velocities in both the clean limestone and shale. However, linear relation model gives better result than the other model when both are applied to shaly limestone and shale. The compressional velocity Vp and shear velocity Vs are linearly related to porosity over the range from 0.32 to 0.53 and 0.01 to 0.35% for limestone and shale,respectively, while the volume clay content C ranges from 0 to 60 and 0 to 40% for limestone and shale,respectively. The effect of clay content in reducing velocity is about 0.10 as much as the effect of porosity for Vp and 0.15 as much for Vs in shale and 0.02 as much as the effect of porosity for Vp and 0.03 as much for Vs in limestone. Generally, the effects of porosity and clay content on shear velocity Vs, are larger than on compressional velocity Vp in limestone and shale. Thus a sample with high porosity and clay content tends to have a low Vp/Vs ratio as observed in limestone. Compressional and shear wave velocities Vp and Vs of clean limestone and shale were linearly correlated to the porosity. They are higher than for shaly limestone and shale with the same porosity. The corresponding velocities of clean and shaly limestone and shale decrease with increasing porosity. The matrix velocities for Vp and Vs with porosity and clay content set to zero differ. This implies that a small amount of clay can significantly soften the porous media matrix leading to reduced velocities.

In order to probe further factor affecting flow in porous media we set up a laboratory experiment we came up with **Variability of permeability with diameter of conduit. Adegoke and Olowofela 2004**

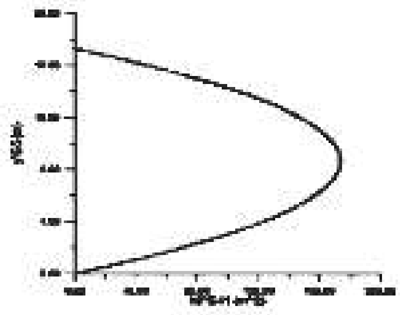
We found out that an entry length is always observed before laminar flow is achieved in fluid flowing in a conduit. This depends on the Reynolds number of the flow and the degree of smoothness of the conduit. This work examined this region and the point where laminar flow commences

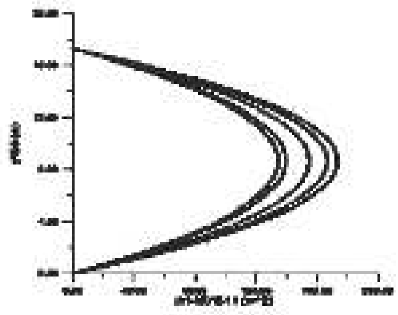
in the context of flow through conduit packed with porous material like beads, of known porosity. Using some theoretical assumptions, it is demonstrated that permeability varies from zero at wall–fluid boundary to maximum at mid-stream, creating a permeability profile similar to the velocity profile. An equation was obtained to establish this. We also found that peak values of permeability increase with increasing porosity, and therefore entry length increases with increasing porosity with all other parameters kept constant. A plot of peak permeability versus porosity revealed that they are linearly related.

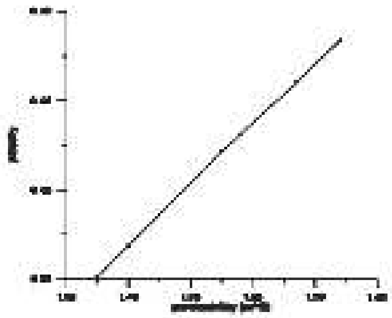
At higher Reynolds numbers, the Poiseuille flow theory applies only after some distance down the pipe. The fluid is unlikely to enter the conduit with the appropriate parabolic velocity profile If the flow enters the pipe from a reservoir through a well-rounded entrance, the velocity at first is almost uniform over the cross-section. The wall shear stress (as the velocity must be zero at the wall) will slow down the fluid near the wall. As a consequence of continuity, the velocity must then increase in the central region. The transition/entry length for the characteristic parabolic velocity distribution to develop is a function of the Reynolds number . Consequently, there is an entry length in which the flow tends towards the parabolic profile. At low Reynolds numbers, this is so short that it can be ignored. But it is found both experimentally and theoretically that as the Reynolds number is increased, this is no longer true. The details of the entry length depend of course on the actual velocity profile at entry, which in turn depends on the detailed geometry of the reservoir and its connection to the conduit. However, an important case which this work is focused on is the situation in which the fluid enters with uniform speed over the whole cross-section, such that there exist zero flow at the fluid–wall boundary and the velocity increases across the mid-stream with the distance of flow. Because of the no-slip condition, the fluid next to the wall must immediately be slowed down. This retardation spreads inward, whilst fluid at the centre must move faster, so that the average speed remains the same and mass is conserved. The fluid flows over a certain length of the pipe before a complete parabolic curve is formed. One thus gets a sequence of velocity profiles. Ultimately, the parabolic profile is approached and from there onwards the Poiseuille flow theory applies.

If the conduit is now packed/filled with porous material, say, beads or sand, we assert that there exists a parabolic profile but this time a permeability parabolic profile. It is necessary to say that Hagen–Poiseuille equation only applies to flow in conduit that is not filled with porous material. But, by introducing the dimensionless parameter Φ, i.e. porosity, to the Hagen–Poiseuille equation, it can then be applied to a situation where the conduit is filled with porous material. With this modification we can now make an assumption that Hagen–Poiseuille equation is equivalent to Darcy equation.

If the velocity changes followed a parabolic profile across a unit cross-sectional area, it is reasonable to think that the permeability k, of the porous medium should follow the same parabolic profile, i.e. the value should not be linear across the cross-section. If a porous system is conceived to be a bundle of capillary tubes of equal radii and length, the permeability k is expected to increase from zero from the wall–fluid boundary towards the centre of the flow.







but still varies across the cross-section. It is worthy to note that the entry length varies with porosity. It is shortest for the least porous medium while it is longest for the more porous medium. The maximum value of permeability which coincided with the point at which transition length is maximum varies with porosity of the medium. The less the porosity of a medium the shorter is the transition/entry length and vice-versa. Specifically, for porous media with porosities 0.361, 0.375, 0.417, 0.448 and 0.467, the entry length was attained when the values of the permeability were 1.35×10^{-9}, 1.40×10^{-9}, 1.55×10^{-9}, 1.67×10^{-9}, 1.74×10^{-9} m^2, that is k_1, k_2, k_3, k_4 and k_5 respectively.

The graph of y (m) against porosity k for porous media with porosity values 0.361, 0.375, 0.417, 0.448 and 0.467 are shown in figures. The figures show the combination of graphs . The innermost curve represents the medium of porosity 0.361 and the next curve is for 0.375 consecutively and the outmost curve is for the medium of porosity 0.467. A graph of porosity against the maximum value of permeability shows that they are linearly related . The equation is said to be valid if the application of it confirmed or conformed with the existing theories. The application of the proposed model as shown in Case 1 where y = 0 and as a result k = 0 indicated the no-slip condition between fluid and the conduit. Case 2 confirmed with an already existing equation.

It can be concluded that the introduction of the dimensionless Φ into Hagen–Poiseuille equation is reasonable and will permit this equation to be applicable to flow in porous media . By the introduction of the dimensionless parameter Φ, to the Hagen–Poiseuille equation, it can then be applied to a situation where the conduit is filled with a porous material.

We equally worked further on

Determination of Transition Length in Flow Through Porous Sand Material. Adegoke and Olowofela 2003

According to Langhaar, 1942 [1], a transition length must be observed when fluid flow from a reservoir to a pipe. If the flow enters the pipe from a reservoir through a well-rounded entrance, the velocity at first is almost uniform over the cross-section. The action of wall shear stress (as the velocity must be zero at the wall) is to slow down the fluid near the wall [2, 3, 4]. As a consequence of continuity, the velocity must then increase in the central region. The transition length/entry length L´ for the characteristic parabolic velocity distribution to develop is a function of the Reynolds number. Langhaar (1942) developed the theoretical formula:

$$\frac{L'}{D} = 0.058R$$

where R is Reynolds number and D is the diameter of the pipe. The flow regime within this region is not laminar, it is after this length/distance that laminar flow is attained and at which point Darcy law applies. By implication, when fluid flows into a pipe Darcy law only applies to the middle segment of the flow; the first segment has the possibility of being turbulent and the last segment being affected by end factor.

Generally, the Darcy equation is given as

$$V_l = \frac{k}{\mu}\nabla(p - \rho g z)$$

which can be re-expressed as;

$$V_l = \frac{k}{\mu}\left(\frac{dp}{dl} - \rho g\frac{dz}{dl}\right)$$

where V_l is the volume flux across a unit area of the porous medium in unit time along flow path l; $\frac{dp}{dl}$ is the pressure gradient along l at the point to which

$$\frac{dp}{dl} = sin6$$

where μ is the angle between l and the horizontal. It can also be deduced that;

$$\frac{dp}{dl} = \rho g sin\theta - V_l\frac{\mu}{k}$$

For an horizontal flow:

$$\frac{dz}{dl} = 0$$

If a sample is completely saturated with an incompressible fluid, then;

$$\frac{dp}{dl} = -V_l \frac{\mu}{k}$$

μ is the viscosity, k permeability and V_l is the Volume flux across a unit area of the porous medium in unit time along flow paths.

Four samples of Riverbed sand were prepared having porosities 0.361, 0.375, 0.446 and 0.467. A cylindrical plastic material of diameter 3.45 x 10^{-2} m and length 2.0m was drilled at an interval of 0.2m along a straight axis. Each drilled hole has a diameter of 4mm and with the use of plasticine, the holes were blocked. One end of the pipe was screened and blocked. Placing it vertically, it was filled with water half way up. Prepared samples were soaked overnight to prevent 'swelling' which may be as a result of the possibility of the presence of microorganism
The samples were poured into the cylindrical tube half-filled with water so as to eliminate trapped air which will obviously affect free flow of water. This precaution is also very necessary so that uniform compaction may be ascertained in all the samples . The other upper end is then screened so that we have a column of pipe that is completely filled with porous sand. With an elbow joint, a similar pipe drilled at 0.06m from the axis of the 2.0 m length pipe is joined and we have an L-shaped structure of piezometric height of 0.06m.
There is inflow from a reservoir into the pipe and to maintain a constant water head (0.06m) a pipe is connected at the hole drilled at that point which drains off excess water. The water head was maintained, purposely because of the measuring range of the manometer used.
The measuring range of the manometer used could not be exceeded by pressure measured at points close to the end of the pipe. The values of pressure at each point were obtained from the waterhead read off from the manometer at that point.

In the figure, pressure increases along the direction of flow from the entry point into the pipe. An optimum is reached at 0.6m down the flow line. This region may be described as a segment the fluid must flow before the parabolic curve is properly and completely built up. Within this region, the flow can be said to be fairly turbulent possibly because of the surge of the influx vis-à-vis the existing piezometric height. After this point of inflexion, pressure decreases with distance of flow. Figures show the segment truncated and the result satisfies Darcy's law, using equation

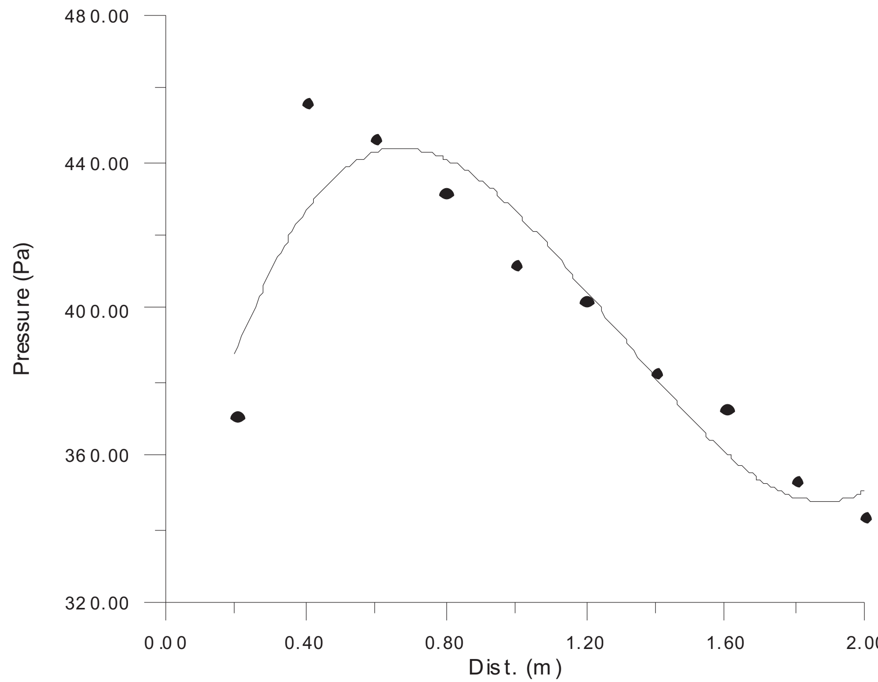


Figure 8: Graph of Pressure versus Distance Sample A.

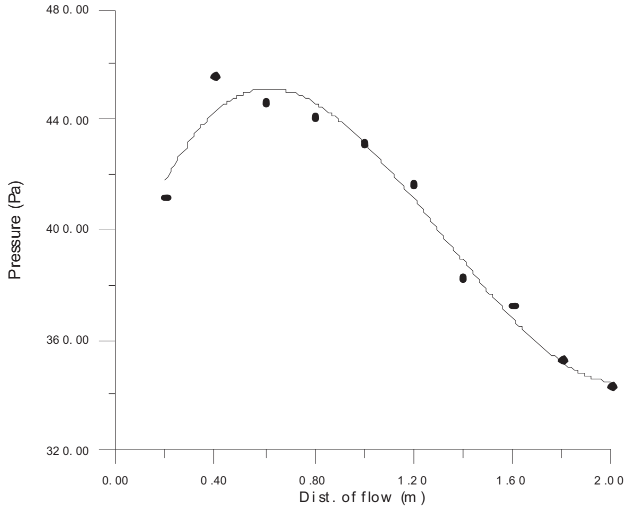


Figure 9: Graph of Pressure versus Distance for Sample B.

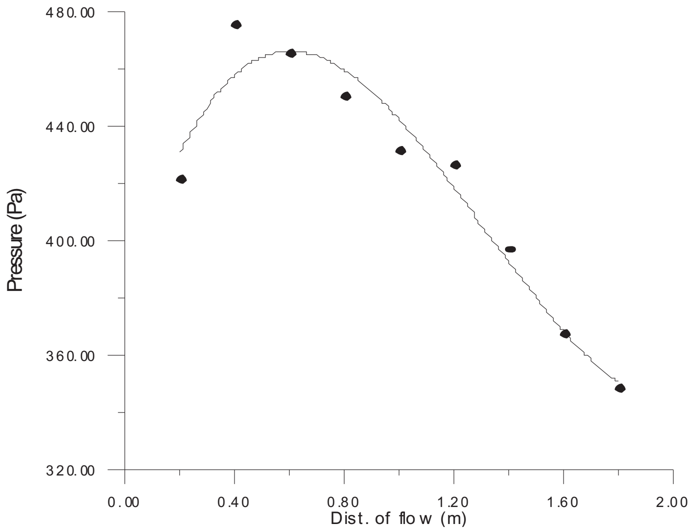


Figure 10: Graph of Pressure versus Distance for Sample C

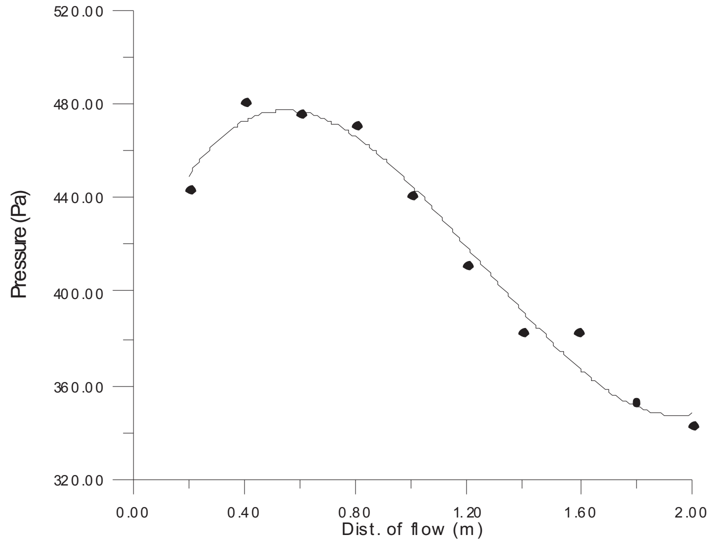


Figure 11: Graph of Pressure versus Distance for Sample D

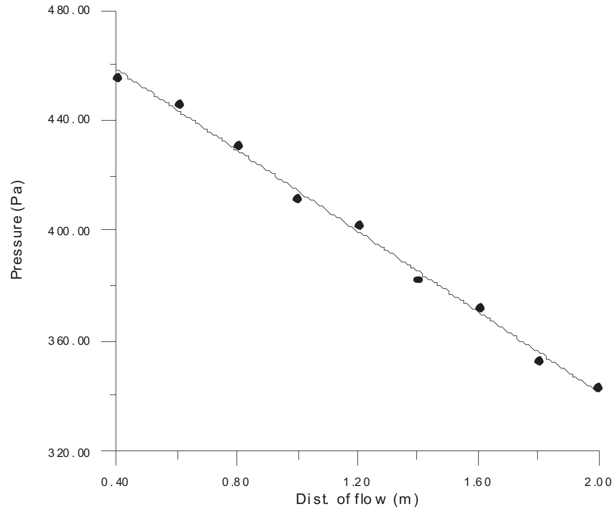


Figure 12: Graph of Pressure versus Distance for Sample A, Neglecting the Entry Length.

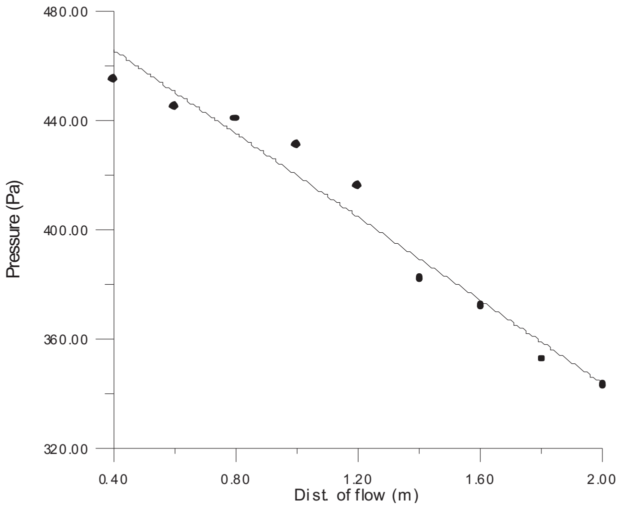


Figure 13: Graph of Pressure versus Distance for Sample B, Neglecting the Entry Length.

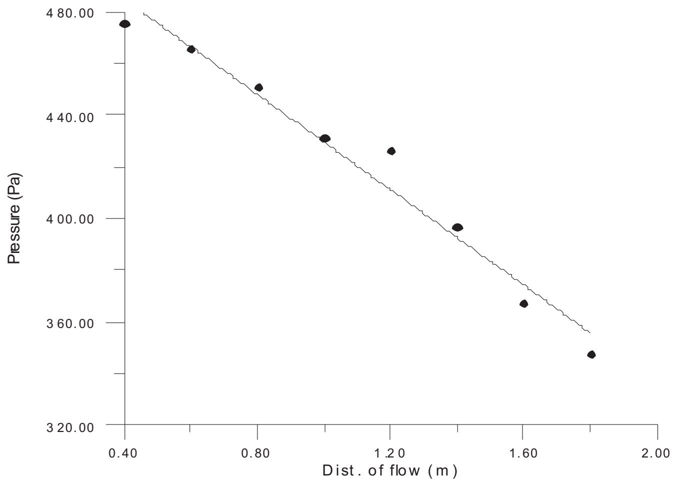


Figure 14: Graph of Pressure versus Distance for Sample C, Neglecting the Entry Length.

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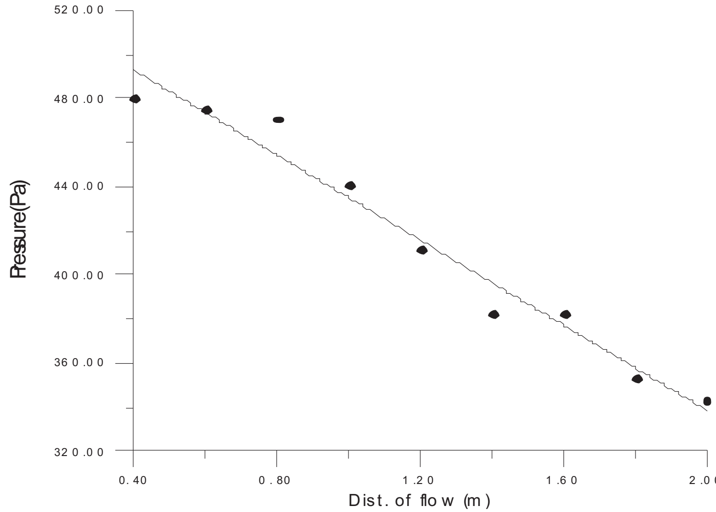


Figure 15: Graph of Pressure versus Distance for Horizontal Flow for Sample D, Neglecting the Entry Length.

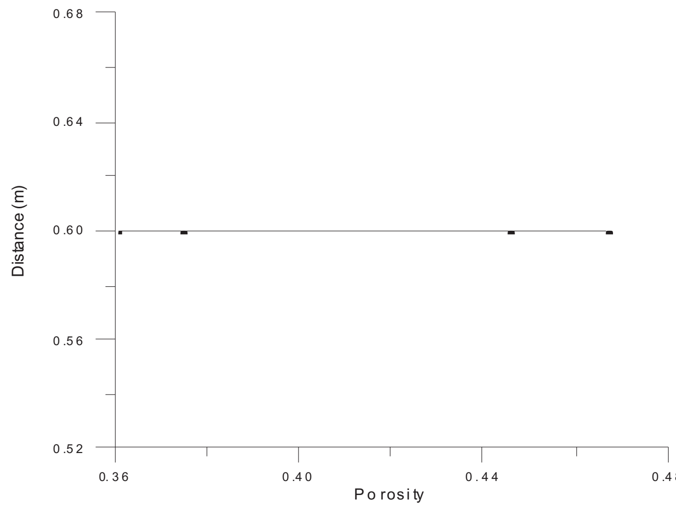


Figure 16: Graph of Transition Distance versus Porosity.

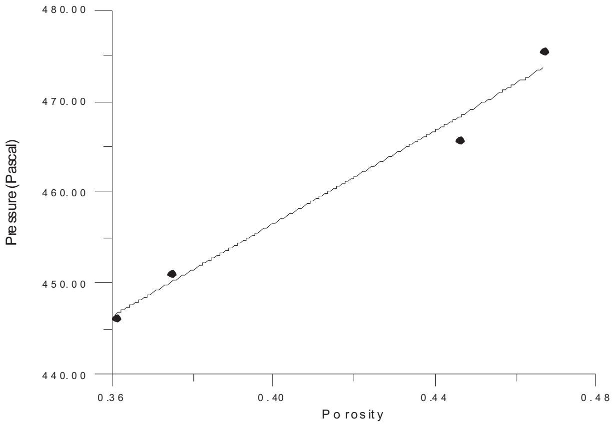


Figure 17: Graph of Peak Pressure at Transition Length/Distance versus Porosity.

Table 2: Values of Pressure and their Corresponding Distances for samples A-D at angle $\theta = 0^0$

Distance; L (m)	Pre.(Pa);A_0	Pre. (Pa);B_0	Pre. (Pa) -C_0	Pre. (Pa);D_0
0.20	370.6914	411.8793	421.6859	444.2412
0.40	456.0092	456.0092	475.6225	480.5258
0.60	446.2026	446.2026	465.8159	475.6225
0.80	431.4926	441.2993	451.1059	470.7192
1.00	411.8793	431.4926	431.4926	441.2993
1.20	402.0727	416.7826	426.5893	411.8793
1.40	382.4594	382.4594	397.1693	382.4594
1.60	372.6527	372.6527	367.7494	382.4594
1.80	353.0394	353.0394	348.1361	353.0394
2.00	343.2328	343.2328		343.2328

* A_0, B_0, C_0, D_0, *represents samples at angle* $\theta = 0^0$

Table 3: Peak Value of Pressure at Constant Distance of Flow and the Porosity of Each Sample.

Sample	Porosity	Distance of flow at peak value (m)	Pressure (Pa) at peak value
A	0.361	0.6	446.2
B	0.375	0.6	451.2
C	0.446	0.6	465.8
D	0.467	0.6	475.6

Transition length exists in flows in porous media as it had been confirmed in flows through conduit. It was observed that Darcy law does not apply in the early segment of the flow and after this segment, pressure decreases along the line of flow and the corresponding value of pressure from one point to the other increases as porosity increases. The transition length is independent of the porosity of the medium but the peak pressure varies linearly, that is, increases with increase in porosity. The entry/transition length was obtained to be 0.60m and the diameter of the pipe was 3.45 x 10^{-2}m with piezometric height of 0.060m.

6.0 Seismics

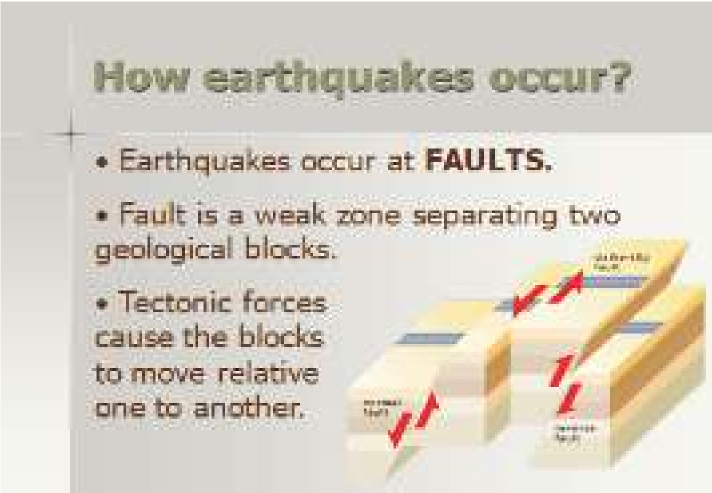
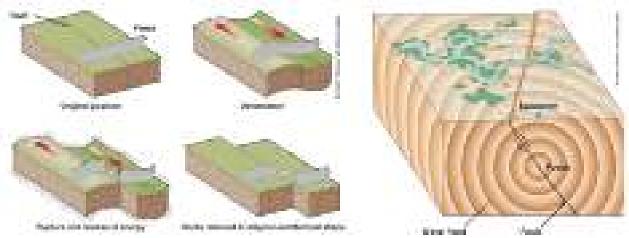


Figure18: How earthquakes occur

How earthquakes occur?
Elastic rebound theory



• Because of friction, the blocks do not slide, but are deformed.
• When the stresses within rocks exceed friction, rupture occurs.
• Elastic energy stored in the system, is released after rupture in waves that radiate outward from the fault.

Fig. 19 Elastic Rebound theory

Elastic waves – Body waves

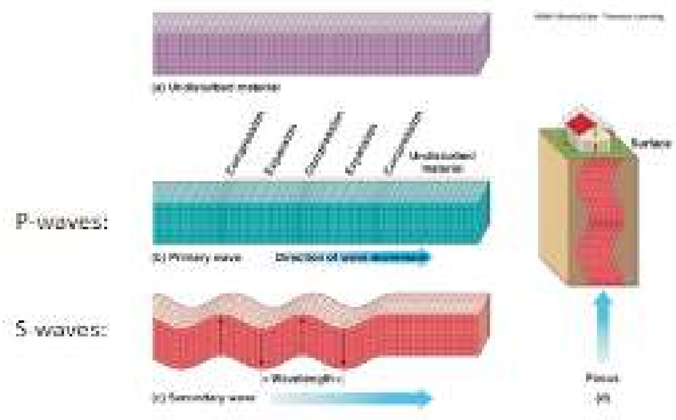


Fig. 20 Body Waves

Elastic waves – Surface waves

Surface waves: Rayleigh and Love waves
- Their amplitude diminishes with the depth.
- They have large amplitudes and are **slower** than body waves.
- These are dispersive waves (large periods are faster).

Fig.21Surface Waves

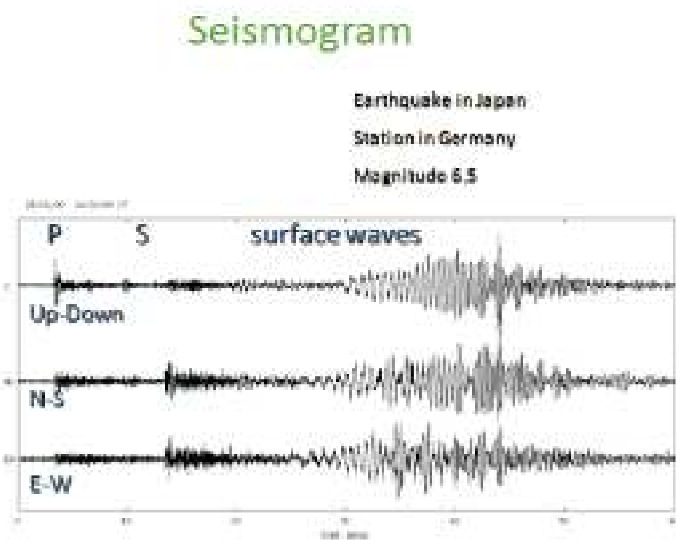


Fig. 22 Seismogram

6.1 Seismic Waves

A seismic wave is acoustic energy transmitted by vibration of rock particles. Low-energy waves are approximately elastic, leaving the rock mass unchanged by their passage, but close to a seismic source the rock may be shattered and permanently distorted.

6.1.1 Types of elastic wave

When a sound wave travels in air, the molecules oscillate backwards and forwards in the direction of energy transport. This pressure or 'push' wave thus travels as a series of compressions and rarefactions. The pressure wave in a solid medium has the highest velocity of any of the possible wave motions and is therefore also known as the primary wave or simply the P wave. Particles vibrating at right angles to the direction of energy

flow (which can only happen in a solid) create an S (shear, 'shake' or, because of its relatively slow velocity, secondary) wave. The velocity in many consolidated rocks is roughly half the P-wave velocity. It depends slightly on the plane in which the particles vibrate but these differences are not significant in small-scale surveys. P and S waves are body waves and expand within the main rock mass. Other waves, known as Love waves, are generated at interfaces, while particles at the Earth's surface can follow elliptical paths to create Rayleigh waves. Love and Rayleigh waves may carry a considerable proportion of the source energy but travel very slowly. In many surveys they are simply lumped together as the ground roll.

6.1.2 Seismic velocities

The 'seismic velocities' of rocks are the velocities at which wave motions travel through them. They are quite distinct from the continually varying velocities of the individual oscillating rock particles.

Any elastic-wave velocity (V) can be expressed as the square root of an elastic modulus divided by the square root of density (ρ). For P waves the elongational elasticity, j is appropriate, for S waves the shear modulus, μ. The equations:

$$V_p = (j/\rho) \quad V_s = (\mu/\rho)$$

suggest that high density rocks should have low seismic velocities, but because elastic constants normally increase rapidly with density, the reverse is usually true. Salt is the only common rock having a high velocity but a low density.

If the density and P and S wave velocities of a rock mass are known, all the elastic constants can be calculated, since they are related by the equations:

$(Vp/Vs)^2 = 2(1-\sigma)/(1-2\sigma)$ $\sigma = [2-(Vp/Vs)2]/2[1-(Vp/Vs)^2]$

$\lambda = q(1-\sigma)/(1+\sigma)(1-2\sigma)$ $\mu = q/2(1+\sigma)$ $K = q/3(1-2\sigma)$

where σ is the Poisson ratio, q is the Young's modulus and K is the bulk modulus. It follows that $\lambda = K + 4\mu/3$ and that a P wave always travels faster than an S wave in the same medium. The Poisson ratio is always less than 0.5. At this limit, Vp /Vs is infinite.

In our research effort, we have course to carry out the following work in seismics **Stability Analysis for Finite Difference Scheme Used for Seismic Imaging Using Amplitude and Phase J.A.Olowofela and Ajani O.O.2013**

A finite difference scheme is produced when partial derivatives in the partial differential equation(s) governing a physical phenomenon like the propagation of seismic waves through real media are replaced by a finite difference approximation. The result is a single algebraic equation which, when solved, provide an approximation to the solution of the amplification factor and celerity for the components of the numerical solution original partial differential equation at selected points of a solution grid. Stability of a numerical scheme like that of finite difference scheme in the solution of partial differential equations is crucial for correctness and validity and it means that the error caused by small perturbation in the numerical solution remains bound. This paper considers important concepts like the amplitude and phase portrait used to analyze the stability of finite difference scheme. Applying these concepts produces an amplification factor and celerity for the components of the numerical solution.

In our further effort we also worked on the:

Determination of the frequency equation for three-dimensional Rayleigh waves in vertically inhomogeneous media. Olowofela J.A., Obawole A.O., and Oni E. 2005

Rayleigh waves or ground rolls are waves that are usually confined to the surface. Their counterparts are Love waves

The propagation of Rayleigh waves in a three-dimensional medium is investigated. Equations for the propagation of Rayleigh waves in three dimensions with the medium assumed to be vertically inhomogeneous have been derived. We also find the frequency equation for this wave and show that for an inhomogeneous medium, the frequency equation is complex, which naturally leads to the fact that phase properties of the frequency equation as well as the magnitude can be used to determine the properties of the material as highlighted in this paper. We find that inhomogeneity has little effect on the propagation of Rayleigh waves when thesoil stiffness G (or modulus of rigidity μ) is 0.6 and above, but it is highly significant when G

We have derived the frequency equation for three-dimensional Rayleigh waves in a vertically inhomogeneous (slowly varying) medium. It is generally believed that for soil models in geodynamics, local variation in material characteristics is not important (homogeneity) and within a wavelength (usually about 10 m for a frequency of 40 Hz and c-400 m s^{-1}) soils are assumed to be homogeneous. While this may be true when soil stiffness G is 0.6 and above, this is not really true for G (values of the modulus of rigidity or soil stiffness.

7.0 RADIOMETRIC SURVEYS

The radioactivity of rocks is monitored using gamma-ray scintillometers and spectrometers. Although most radiometric instruments were developed with uranium search in mind, other uses were soon found. Among these were regional geological mapping and correlation, exploration for some industrial minerals and in situ determinations of phosphates. The same instruments may also be used to track the movement of artificial radioactive tracers deliberately introduced into groundwater, and to assess health risks from natural and artificial radiation sources. Radon gas detectors, which monitor alpha particles, have some exploration uses but are most important in public health applications.

7.1 Natural Radiation

Spontaneous radioactive decay produces alpha, beta and gamma radiation.

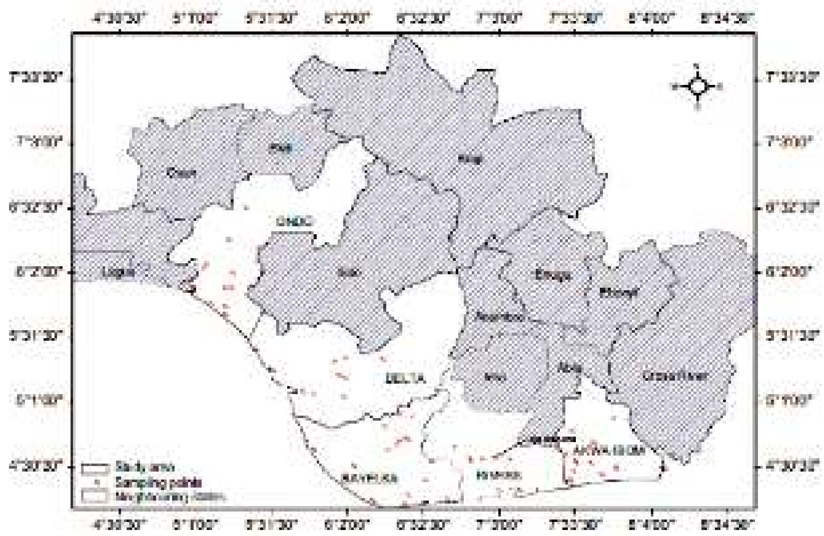
Alpha and beta 'rays' are actually particles; gamma rays are high-energy electromagnetic waves which, so quantum theory tells us, can be treated as if composed of particles.

We carried out a research on

Distribution of some natural gamma-emitting radionuclides in the soils of the coastal areas of Nigeria. O.O.Alatise, I.A.Babalola and J.A.Olowofela 2008

The two prominent sources of external radiation are cosmic rays and terrestrial gamma-rays which are derived mainly from naturally occurring radioactive materials (NORM). These naturally occurring radioactive materials which are present in soils have been shown to contribute at least 85% of the natural background radiation (IAEA, 1987). This implies that NORM have been the largest contributors to the collective dose received by the world population. Apart from natural

sources, many research and technological activities also contribute to the radiation level in the environment. Oil and gas production and processing operations sometimes cause NORM to accumulate at elevated concentrations in by-product waste streams. The improper use and disposal of NORM can also result in significant contamination of the environment world's oil and gas production (Reijers et al., 1996). The vegetation prevalent in the study areas is the swamp forest which is common to the coastal areas of Nigeria.



CONCLUSION

We have been able to combine Instrumentations and constructions of physical equipments, available in any standard physics laboratory, to investigate the interior of the earth. Furthermore we applied mathematical modeling and computational skills, for many of the presentation in this lecture.

As at 2018 the total number of Universities in Nigeria is 158 with less than 2000 Geophysicists in these institutions. For a population of over 170 Million people, the intellectual "where house" of this subject is abysmally low. The reasons, for this is not difficult to know, this is largely due to high cost of setting up geophysics research. However, if we can be creative and ingenuous in our approach, as demonstrated in this lecture,we shall be able to produce quality and adequate man powers (in Solid Earth Geophysics) in the country

and open ways to financial prosperity .

Once gain, I thank the management of the University, for the opportunity granted me to present the lecture.

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DEDICATION

This inaugural lecture is dedicated to God Almighty for His faithfulness and all my 'children' in the academia from whom I have learnt much more than they ever learnt from me.