Evaluation of Physical Parameters of Various Solid Minerals within Southwestern Nigeria Using Direct Experimental Laboratory Methods

B. S. Badmus
Department of Physics
Federal University of Agriculture, Abeokuta
P.M.B 2240, Abeokuta, Ogun State. Nigeria.

O. T. Olurin
Department of Physics
Federal University of Agriculture, Abeokuta.
P.M.B 2240, Abeokuta, Ogun State. Nigeria.

S.A. Ganiyu
Department of Physics
Federal University of Agriculture, Abeokuta.
P.M.B 2240, Abeokuta, Ogun State. Nigeria.

O. T. Oduleye
Department of Physics
Federal University of Agriculture, Abeokuta.
P.M.B 2240, Abeokuta, Ogun State. Nigeria.

Abstract

Physical parameters of some solid minerals spread across the southwestern, Nigeria: quartz, gneiss, feldspar, limestone, kaolin, mica schist, pegmatite with mica and phosphate were analyzed using direct laboratory approach of resistivity, permeability, bulk density and porosity. Core samplers of three major shapes (cubic, cylinder and bar) were used for resistivity measurement at different direct voltages of 3V, 5V and 8V. The results obtained from these analyses were comparable with standard resistivity values in literature. Results from permeability and porosity revealed kaolin clay to be highly permeable with higher degree of porosity when compared with phosphate, gneiss, quartz and feldspar. However, kaolin clay has the least bulk density of 235.4Kg/m^3 *while phosphate revealed the highest value of 360.15Kg/*m^3.

Keywords: Permeability, Solid Minerals, Resistivity Values, Bulk Density, Porosity.

1.0 Introduction

Rocks are naturally occurring solid material consisting of one or more minerals. Minerals are solid, naturally occurring chemical elements or compounds that are homogenous, having definite chemical composition and arrangement of atoms. Rocks are everywhere, in the ground, forming mountains, and at the bottom of the oceans. Earth’s outer layer, or crust, is made mostly of rock which includes granite and basalt. Rock forming minerals have conductivities spreading over a wide range and most rock forming minerals are semi-conductors in dry form (i.e., rocks are insulators). The amount of moisture contained in the rock depends on the amount of pore spaces. Rock and sediment contain space between grains in fractures or in dissolved cavities, which may now become filled with water. The porosity and chemical content of the water filling the pore spaces are more important in the resistivity than conductivity of the minerals. To be classified as a true mineral, a substance must be a solid and have a crystalline structure. It must also be a naturally occurring, homogeneous substance with a defined chemical composition. Minerals fall into one of the six basic crystal systems. This crystal structure is based on regular internal atomic arrangement that is often expressed in geometric form that the crystal takes.

Chemistry and crystal structure together define a mineral. There are currently more than 4,000 known minerals. Of these, perhaps 100 can be called common and the rest are "rare" to "extremely rare." Some rocks are predominantly composed of one mineral. For example, limestone is a sedimentary rock composed almost entirely of the mineral calcite. Other rocks contain many minerals and the specific minerals in a rock can vary widely from one rock to the other. Some minerals, like quartz, mica or feldspar are common, while others have been found in only one or two locations worldwide. The vast majority of the rocks of the earth's crust consist of quartz, feldspar, mica, chlorite, kaolin, calcite, epidote, olivine, augite, hornblende, magnetite, hematite and limestone. Commercially valuable minerals and rocks are referred to as industrial minerals while rocks from which minerals are mined for economic purposes are referred to as ores.

The main determining factor in mineral forming rock is the chemical composition. Calcite is most common in limestone, as these consist essentially of calcium carbonate; quartz is common in sandstones and in certain igneous rocks which contain a high percentage of silica. Other factors are of equal importance in determining the nature of rock-forming minerals, principally the mode of origin of the rock and the stages through which it has passed in attaining its present condition. Two rock masses may have same bulk composition and yet consist of entirely different assemblages of minerals. Granite is created by consolidation of molten magma at high temperatures and great pressures with its mineral component stable under such conditions. Exposed to moisture, carbonic acid and other agents at the ordinary temperatures of the Earth's surface, some of these original minerals, such as quartz and white mica are relatively stable and remain unaffected; others weather or decay and are replaced by new combinations. These changes are accompanied by disintegration, and the rock falls into a loose, incoherent, earthy mass which may be regarded as sand or soil. The materials thus formed may be washed away and deposited as sandstone or siltstone. This paper is aimed at analyzing rock forming minerals and compares the electrical resistivity values as well as other physical parameters using laboratory direct methods.

2.0 Brief Description of the Solid Minerals

2.1 Quartz

Quartz is the second most abundant mineral in the Earth's continental crust, after feldspar. It is made up of a continuous framework of SiO_4 silicon–oxygen tetrahedral, with each oxygen being shared between two tetrahedral, giving an overall formula SiO_2. It is a colourless, odourless, non-combustible solid and a component of many mineral dusts; insoluble in water. When quartz is cut, grounded, or milled, the crystal is fractured; Si and Si-O radicals may be generated on the cleavage surfaces (Castranova et al., 1996). Trace metal impurities, such as iron and aluminum can modify the surface reactivity of quartz (Fubini et al., 1995; IARC, 1997; Donaldson and Borm, 1998). It has a hardness of seven on the moh -hardness scale, which makes it very abrasion resistant. This usually makes flaking difficult and produces flat or linear flakes. It is difficult to find a high quality form of quartz because it contains veins, cracks and other flaws. It is the combination of these variables that makes quartz flake differs from cryptocrystalline materials.

Quartz also occurs in two different types: crystalline and cryptocrystalline. The cryptocrystalline include jasper, chalcedony, flints, charts and agates, which are known to be easily knappable and occur commonly in archaeological sites. Crystalline quartz is of two different forms: crystal and crystalline. It is the source of many silicon compounds such as silicones and many other compounds of commercial importance. Owing to its high thermal, chemical stability and abundance, quartz is widely used on large-scale applications as abrasives, foundry materials, ceramics, and cements.

2.2 Pegmatite

A pegmatite is a crystalline, intrusive igneous rock composed of interlocking crystals usually larger than 2.5cm in size; referred to as pegmatite. It is composed of quartz, feldspar and mica. Rare intermediate composition and mafic pegmatite containing amphibole, ca-plagioclase feldspar, pyroxene and other minerals are known, found in recrystallized zones and apophyges associated with large layered intrusions. Crystal size is the most striking feature of pegmatites, usually over 5.0cm in size (Gonzalez - Munoz et al, 2007).

2.3 Mica Schist

Schist, term applied to any of several metamorphic rocks in which the crystals of the predominating mineral are aligned in parallel layers, forming a large number of close, well-developed foliations.

Schistose rocks are easily broken along a lamination, or schistosity, into thin, flaky plates. The various schistose rocks are named and characterized according to the predominating mineral that produces the foliation. Among the important schist is mica schist, hornblende schist, chlorite schist, and talc schist. Quartz is usually the predominant secondary mineral. The most common schistose rock are second to gneiss while the most common metamorphic rock, is mica schist. Mica schist is composed of mica, usually in the form of biotite or muscovite, and smaller amounts of quartz. Garnet-mica schist is a mica schist containing crystals of garnet.

2.4 Mica

Chemically, mica has a general formula: $X_2Y_4\,6Z_8O_20$ (OH, F) 4 where X is K, Na, or Ca or less commonly Ba, Rb, or Cs; Y is Al, Mg, or Fe or less commonly Mn, Cr, Ti, Li, etc. Z is chiefly Si or Al, but also may include Fe^{3+} or Ti. Structurally, mica can be classified as dioctahedral (Y = 4) and trioctahedral (Y = 6). If the X ion is K or Na, then the mica is 'common'mica, whereas if the X ion is Ca, the mica is classified as a 'brittle' mica. Fine-grained mica, with more variation in ion and water content, is termed "clay micas". Mica is widely distributed and occurs in igneous, metamorphic and sedimentary regimes. Large crystals of mica used for various applications are typically mined from granitic pegmatites. Until the 19th century, large crystals of mica were quite rare and expensive as a result of the limited supply in Europe. In paint industry, ground mica is used as a pigment extender that also facilitates suspension, reduces chalking, prevents shrinking and shearing of the paint film, increases resistance of the paint film to water penetration and weathering, and brightens the tone of colored pigments.

Mica also promotes paint adhesion in aqueous and oleoresinous formulations. Ground mica is used in the well-drilling industry as an additive to drilling fluids. The coarsely ground mica flakes help prevent the loss of circulation by sealing porous sections of the drill hole. Sheet mica is used principally in the electronic and electrical industries. Its usefulness in these applications is derived from its unique electrical and thermal insulating properties with its mechanical properties, which allow it to be cut, punched, stamped, and machined to close tolerances.

2.5 Kaolin

Kaolin (china clay) is a hydrated aluminum silicate crystalline mineral (kaolinite) formed over many millions of years by the hydrothermal decomposition of granite rocks. Hydrous kaolin is characterized by its fine particle size, plate like or lamellar particle shape with chemical inertness. It is named after the hill in China (Kao-Ling) where it was first mined, for many years before its discovery in Europe in 1745. It is colour white, sometimes red, blue or brown tints from impurities. Kaolinite is a clay mineral, part of the group of industrial minerals, with the chemical composition $Al_2Si_2O_5\,(OH)_4$. It is a layered silicate mineral, with one tetrahedral sheet linked through oxygen atoms to one octahedral sheet of alumina octahedral. It is a soft, earthy, usually white mineral (dioctahedralphyllosilicate clay), produced by the chemical weathering of aluminum silicate minerals like feldspar. Chemical analysis carried out on kaolin clay show that it is acidic and contains high concentration of alkaline metals. The physical analyses also reveal kaolin clay to have an average porosity of 0.46 and bulk density of 1.4 g cm^{-3}, (Badmus and Olatinsu, 2009). Kaolin is now used in the ceramics, paper, paint, plastic, rubber, sealant, adhesives and chemicals industries. The coarse kaolin can be used in flooring compounds to increase abrasion resistance as well as making the compound cheaper. In sealants and adhesives, kaolin is used to modify rheological properties.

2.6 Feldspar

This group of minerals is characterized by the chemical composition and structural state (Mernagh, 1991). Based on the proportion of K, Na and Ca, feldspar can be classified further into two main groups: alkaline feldspar and plagioclase. Feldspar is in the series between $NaAlSi_3O_8$ and $CaAl_2Si_2O_8$ (Mernagh, 1991). Plagioclase can be further divided into six subgroups: *albite, oligoclase, andesine, labradorite, bytownite and anorthite*. The red colour causing agent or chromospheres in labradorite is copper (Cu). Depending on the copper particle size, concentration of copper and the temperature at which its solution is initiated, a red colour or schiller effect can be achieved (Hofmeister and Rossman, 1985). The potassium or K-feldspars are polymorphs, having the same chemistry, $KAlSi_3O_8$, but different structures and therefore are different minerals. The plagioclase feldspars are a set of minerals that are in series from a sodium rich end member, albite, to a potassium rich end member, anorthite. The different feldspars are distinguished by their structure and chemistry (Gonzalez - Munoz et al, 2007).

All feldspars have low symmetry, being only monoclinic to triclinic. Feldspars also tend to crystallize in igneous environments, but are present in many metamorphic rocks.

2.8 Limestone

Limestone is a sedimentary rock composed largely of the minerals calcite and aragonite, which are different crystal forms of calcium carbonate ($CaCO_3$). Like most other sedimentary rocks, limestone is composed of grains; however, most grains in limestone are skeletal fragments of marine organisms such as coral or foraminifera. When inter-ground with Portland cement clinker, it produces an improved particle size distribution and improved particle packing. Fine limestone particles act as nucleation sites, increasing the rate of hydration of the silicates.

Limestone is readily available and relatively easy to cut into blocks or more elaborate carving. It is also long-lasting and stands up well to exposure. However, it is a very heavy material, making it impractical for tall buildings, and relatively expensive as a building material. Limestone and marble are reactive to acid solutions, making acid rain a significant problem to the preservation of artifacts made from this stone. It is the raw material for the manufacture of quicklime (calcium oxide), slaked lime (calcium hydroxide), cement and mortar. Pulverized limestone is used as a soil conditioner to neutralize acidic soils. It is crushed for use as aggregate—the solid base for many roads. Geological formations of limestone are among the best petroleum reservoirs and it is a reagent in flue-gas desulfurization, it reacts with sulfur dioxide for air pollution control. It can be used for remineralizing and increasing the alkalinity of purified water to prevent pipe corrosion and to restore essential nutrient levels (Newman and Banfield, 2002).

2.9 Phosphate

Most of the world's phosphate fertilizers are produced from phosphate rock resources and almost all of these resources contain some form of the mineral apatite. There are many phosphate rock deposits and occurrences in sub-Saharan Africa. Soil acidity with associated Al toxicity, as well as P and Ca deficiencies, are common growth-limiting factors in highly leached tropical soils. Low crop yields occur on strongly nutrient depleted acid oxisols and ultisols. To overcome the specific phosphate nutrient deficiency in soils, various forms of phosphate are applied. Inorganic phosphate sources applied to the soils range from processed phosphate rocks (P-fertilizers) to ground phosphate rocks and slightly modified forms of phosphate rock. The use of commercial phosphate fertilizers, initially designed for soils in the northern hemisphere is often not cost effective on these strongly depleted weathered soils of the tropics, as the phosphate ions are easily 'sorbed' by aluminum and iron oxide minerals.

Phosphate rock is a globally accepted but imprecise term describing any naturally occurring geological material that contains one or more phosphate minerals suitable for commercial use. The rock comprises both the unprocessed phosphate ore as well as the concentrated phosphate products (Notholt and Highley, 1986). The phosphorus content or grade of phosphate rocks is commonly reported as phosphorus pentoxide (P_2O_5). The principal phosphate minerals in Phosphate rocks are Ca-phosphates, mainly apatites. Five major types of phosphate resources are being mined in the world: marine phosphate deposits; igneous phosphate deposits; metamorphic deposits; biogenic deposits; phosphate deposits as a result of weathering (Newman and Banfield, 2002).

2.91 Gneiss

Gneiss is a metamorphic rock whose minerals have been segregated into parallel layers, creating a banded or laminated structure. The metamorphosis of many igneous and sedimentary rocks has resulted in a banded structure in which the quartz and feldspar are segregated into layers that alternate with layers of dark minerals. The different varieties of gneiss are named after the type of rock from which they have been formed (as granite gneiss and diorite gneiss) or after a mineral in which the rock is unusually rich (as biotite gneiss and hornblende gneiss).

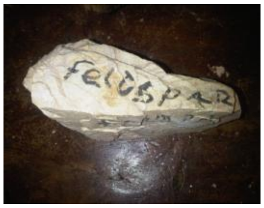
The different rock samples considered in this research work are shown in figure below.

Quartz

Mica with pegmatite

Pegmatite with mica schist

Kaolin



Feldspar

Limestone

Phosphate

Figure 1.0: Rock Samples of the Solid Minerals

3.0 Methodology

A total of eight rocks samples were analyzed to obtain their physical parameters: resistivity, permeability or saturated hydraulic conductivity, porosity and density.

3.1 Direct Laboratory Measurement of Resistivity Using D.C Supply

The rock samples were grounded into powder form and packed into core sampler of different shapes: cylindrical, cubic and bar shapes of regular cross sectional area. These shapes are specifically used, because only standard shapes can be used to find the resistance of rocks when using direct laboratory approach as shown in figure 2. The rock samples were then saturated for 24 hours hydraulically, after which the rock samples were oven dried to remove all the water content in the samples. This was done to put the sample into regular shape form and also to make contact with the pins (conducting metal) that was inserted into the core sampler. D.C power was supply to the ends of the core sampler. Voltage was varied and resistance of the individual rock of different shapes was obtained. The resistivity values of the different shapes were them compared for interpretation.

Radius of core sampler = $0.021m^2$

Area of bar: $l \times b = 0.0035m^2$

Area of cube: $6l^2 = 0.0054m^2$

Area of cylinder: $2\pi r[r+h] = 0.0094m^2$.

$\mathrm{p} = \frac{VA}{IL}$, where ρ = resistivity value, V= voltage, L = Length of the sample inside the core sampler.

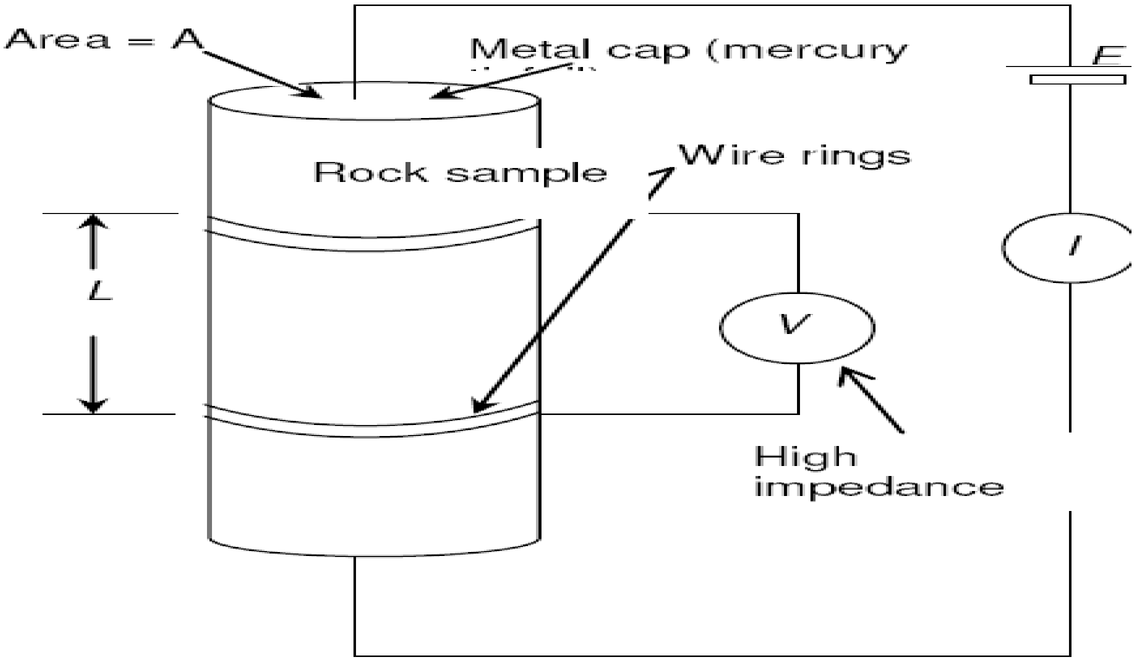


Figure 2.0: Direct Experimental Set-up

3.2 Permeability and Porosity

Permeability and porosity are the two primary properties that control the movement and storage of fluids in rocks. They are important indicators for the utilization of various kinds of rocks (Huenges and Zimmermann, 1990).

$$POROSITY = 1 - \frac{Volumeofsolid}{TotalVolume},\qquad \textbf{Volume of solid} = \frac{massofsolid}{density},$$

$$\textbf{Total volume} = \frac{\pi L d^2}{4} = \mathbf{6.93 \times 10^{-5} m^3}$$

Permeability is the ability of porous material to allow the passage of a fluid. To determine permeability of rocks, various methods can be applied, which differ in the medium used. In the case when the fluid that passes through the porous material is water, permeability can be expressed by the coefficient of conductivity k ($m.s^{-1}$), which means a discharge velocity of water flow in a rock under the action of a unit hydraulic gradient, usually expressed in meters per second.

$k_{sat} = \frac{QL}{Aht}$ Where Q is the value of water leaking through the specimen at time t, L, the height of the tested specimen, A is cross-sectional area of the specimen, h, is the difference in the water pressure levels and T, the period of measurement. The conductivity coefficient of porous material is influenced not only by porosity, but also by the shape and arrangement of pores, or by the amount of clayey component. Only effective porosity can influence permeability, because only open pores are interconnected and allow leaking water through. Another important factor is pore size distribution, or amount of clayey component. By evaluating relationship of porosity and permeability, it is also necessary to take into account rock bulk and particle density.

4.0 Result

Tables 1 – 3 show the voltage and current values for the different samples using direct current supply of 3V, 5V and 8V, for the three different shapes. The result revealed that Kaolin has the least values among the rock samples analysed between 1.95×10^3 and 2.03×10^3, while Phosphate has the highest between 13.60×10^3 and $14.90 \times 10^3 \Omega m$ at 3V.

A 5V, the mica schist revealed the least resistivity values between 1.69×10^3 Ωm and $1.76 \times 10^3 \Omega m$ whilst phosphate revealed the highest values between 18.5×10^3 Ωm and $19.30 \times 10^3 \Omega m$ (Table 5). At 8V, pegmatite mixed with mica schist has the least resistivity value between 3.99×10^3 and $4.07 \times 10^3 \Omega m$ while mica schist has highest value ranging between 37.80×10^3 Ωm and $38.30 \times 10^3 \Omega m$ (Table 6). Since resistivity is the reciprocal of conductivity, samples with high resistivity values have low conductivity, a function of porosity and permeability (Tables 7 and 8).

The result obtained from the experimental analyses of permeability revealed kaolin to be highly permeable while gneiss is least among the samples analysed. Mica schist rock revealed the least porosity value of 0.0185 while limestone showed the highest porosity of 0.2612. Kaolin clay revealed the least bulk density of $235.4 Kg/m^3$ while phosphate revealed the highest value of $360.15 Kg/m^3$ (Tables 9 – 11).

Table 1: Voltage and Current at 3V

S/N	Samples	Voltage (V)			Current (μA)		
		Shape Types			Shape Types		
		Cylinder	Bar	Cubic	Cylinder	Bar	Cubic
1	Quartz	0.10	0.12	0.09	7.16	3.14	6.10
2	Gneiss	0.70	0.79	0.69	17.30	7.00	16.00
3.	Feldspar	1.20	1.26	0.90	50.50	17.00	32.00
4.	Limestone	0.90	1.50	0.87	25.00	11.90	18.40
5.	Kaolin	0.50	0.70	0.48	59.00	25.00	47.00
6.	Micah schist	0.50	0.62	0.50	66.00	32.00	64.70
7.	Pegmatite with Micah schist	0.90	0.94	0.88	57.20	22.00	55.80
8.	Phosphate	2.50	2.57	2.46	35.50	13.20	34.90

Table 2: Voltage and Current at 5V

S/N	Samples	Voltage (V)			Current (μA)		
		Shape Types			Shape Types		
		Cylinder	Bar	Cubic	Cylindrical	Bar	Cubic
1.	Quartz	1.00	1.60	0.80	13.70	7.30	9.20
2.	Gneiss	1.50	1.90	1.20	35.40	15.90	26.80
3.	Feldspar	2.50	2.54	2.44	97.60	32.10	83.30
4.	Limestone	1.00	1.04	0.98	33.90	10.20	25.00
5.	Kaolin	0.70	0.76	0.66	47.50	15.90	36.40
6.	Micah schist	1.30	1.29	1.34	145.00	53.40	153.00
7.	Pegmatite with Micah schist	1.50	1.57	1.46	118.20	45.80	111.00
8.	Phosphate	4.00	3.89	4.04	41.50	14.70	42.00

Table 3: Voltage and Current 8V

S/N	Samples	Voltage (V)			Current (μA)		
		Shape Types			Shape Types		
		Cylinder	Bar	Cubic	Cylinder	Bar	Cubic
1.	Quartz	1.90	2.40	1.60	23.50	10.50	19.50
2.	Gneiss	3.10	3.40	2.90	61.50	25.00	52.00
3.	Feldspar	3.60	3.90	3.10	198.60	70.70	146.00
4.	Limestone	2.00	2.50	1.50	46.20	16.00	25.40
5.	Kaolin	1.50	1.56	1.48	50.04	15.80	38.60
6.	Micah schist	2.50	2.45	2.48	12.60	47.30	12.50
7.	Pegmatite with Micah schist	3.90	4.50	3.20	189.4	82.20	152.00
8.	Phosphate	5.30	6.00	4.70	56.40	23.30	50.40

Table 4: Resistivity Value at 3V

Samples	Resistivity (Ω-m)		
	Shape Types		
	Cylinder	Bar	Cubical
Quartz	2.81	2.79	2.80
Gneiss	8.26	8.22	8.30
Feldspar	5.32	5.28	5.36
Limestone	9.15	9.19	9.11
Kaolin	1.99	2.03	1.95
Micah schist	14.53	14.10	14.90
Pegmatite with Micah schist	3.08	3.12	3.04
Phosphate	13.79	14.19	13.60

Table 5: Resistivity Value at 5V

Samples	Resistivity (Ω-m)		
	Shape Types		
	Cylinder	Bar	Cubical
Quartz	16.30	15.90	16.70
Gneiss	8.66	8.70	8.62
Feldspar	5.73	5.77	5.65
Limestone	7.50	7.43	7.56
Kaolin	3.46	3.49	3.50
Micah schist	1.72	1.76	1.69
Pegmatite with Micah schist	2.48	2.50	2.54
Phosphate	18.90	19.30	18.50

Table 6: Resistivity Value at 8V

Samples	Resistivity (Ω-m)		
	Shape Types		
	Cylinder	Bar	Cubical
Quartz	16.20	16.60	15.80
Gneiss	10.30	9.90	10.70
Feldspar	4.06	4.02	4.10
Limestone	11.00	11.30	11.40
Kaolin	7.00	7.20	7.40
Micah schist	38.10	37.80	38.20
Pegmatite with Micah schist	4.03	3.99	4.07
Phosphate	18.40	18.80	18.00

Table 7: Experimental Values of Porosity

Samples	Porosity
Quartz	0.0620
Gneiss	0.0808
Feldspar	0.1602
Limestone	0.2612
Kaolin	0.2002
Micah schist	0.0185
Pegmatite with Micah Schist	0.0402
Phosphate	0.0402

Table 8: Experimental Values of Permeability, K_{Sat}

Samples	Permeability (m/s)
Quartz	1.35×10^{-6}
Gneiss	8.85×10^{-6}
Feldspar	7.68×10^{-7}
Limestone	6.67×10^{-6}
Kaolin	2.12×10^{-5}
Micah Schist	5.07×10^{-6}
Pegmatite with Micah Schist	8.55×10^{-5}
Phosphate	1.96×10^{-6}

Rock Density

Experimental Values of Rock Density

Mass of the core sampler: 0.0129Kg

Table 9: Mass and Volume of Rock Samples

Samples	Mass (Kg)	Volume (m^3)
Quartz	0.0869	6.50×10^{-5}
Gneiss	0.077	6.37×10^{-5}
Feldspar	0.0868	5.82×10^{-5}
Limestone	0.0705	5.12×10^{-5}
Kaolin	0.0525	5.54×10^{-5}
Micah Schist	0.0751	6.80×10^{-5}
Pegmatite with Micah schist	0.0802	6.65×10^{-5}
Phosphate	0.0958	6.65×10^{-4}

$$\text{Bulk Density} = \frac{\text{Mass}}{\text{Volume}}$$

Table 10: Bulk Density

Samples	Bulk Density
Quartz	334.23
Gneiss	289.47
Feldspar	372.53
Limestone	316.14
Kaolin	235.4
Micah	276.10
Pegmatite with Micah schist	301.50
Phosphate	360.15

Saturated Hydraulic Conductivity

Table 11: Saturated Hydraulic Conductivity of Rock Samples

S/N	Samples	T (min)	V (m^3)	R (m)	h (m)	L (cm)
1.	Quartz	5.00	1.20	0.021	0.099	0.047
2.	Gneiss	5.00	0.80	0.021	0.099	0.046
3.	Feldspar	5.00	0.75	0.021	0.099	0.042
4.	Limestone	5.00	7.50	0.021	0.099	0.037
5.	Kaolin	5.00	22.0	0.021	0.099	0.040
6.	Micah schist	5.00	4.30	0.021	0.099	0.049
7.	Pegmatite with Micah schist	5.00	74.1	0.021	0.099	0.048
8.	Phosphate	5.00	1.70	0.021	0.099	0.048

5.0 Conclusion

This study revealed the physical parameters of solid minerals using direct laboratory methods of resistivity, permeability, porosity and bulk density. From the analyses, kaolin clay, mica schist and pegmatite revealed higher degree of permeability and porosity, a confirmation of the features of both sedimentary and weathered rock formations. Phosphate, gneiss, quartz and feldspar revealed lower degree of permeability and porosity as these rock samples belong to basement rocks with little weathering.

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