Correlation Between Dry Densityand Porosity OF Rocksin Josand Its Environs, North-Central, Nigeria

[1]Akanbi E.S., [2]Aboche F.E., [3]Gyobe A.M.; Kozah A.A.[4]; Ibrahim N.Y.[5].

[1&4] *Department of Physics, University of Jos.*
[2&5]*Department of Pure & Applied Physics, Federal University Wukari.*
[3] *Department of Physics, College of Education Akwanga.*

Abstract

The relationship between Density and Porosity of Rocks from Jos and Environs, North Central Nigeria was established using correlation coefficient of the two parameters that always served as guide on engineering design, especially on strength of materials to be considered. The study is located NE of Naraguta sheet 168, on Latitude 9^{o} 55' 00.00"N - 10° 00' 00.00"N and Longitude 8° 45' 00.00" E - 9° 00' 00" E. The Dry Density and Porosity of Rock samples were determined using the Archimedes method guided by the in situ method by Nettleton and Parasnis to determine density, a total of 80 samples were collected. Dry density, Particle density and Porosity were calculated in the laboratory. A correlation was obtained using SPSS and a chart of Porosity vs. Dry Density was plotted. The average Dry Density (g/cm^3) and Porosity (%) values for the rocks samples are: Rukuba Granite Gneiss 2.609 and 1.494; Diorites 2.888 and 0.480; Older Basalt 2.942 and 0.356;Aegerine2.663 and 1.831; Naraguta Quartzite 2.615 and 1.469; Jos Biotite granite 2.578 and 1.880; Migmatite 2.643 and 1.617; Neil valley Granite Porphyry 2.638 and 2.164; Hornblende Biotite granite 2.579 and 1.826 and Rhyolite 2.623 and 0.753. The Correlation coefficient values for the rocks are: Rukuba Granite Gneiss -1.0000; Basalt -1.0000; Neil valley Granite Porphyry-0.8362; Hornblende Biotite Granite -0.2909; Naraguta Quartzite -0.2386; Jos Biotite Granite -0.0784; Aegerine-0.0662; Migmatite 0.07997; Diorites 0.36304 and Rhyolite 1.00. From the results of the research it can deduced that for rocks whose density and porosity are related should be considered during engineering design.

Keywords: *Dry Density; Particle Density; Porosity; Correlation and Rocks.*

I. BACKGROUNG TO THE STUDY

Earth science deals with the study of the earth, its history, changes and its place in the universe. A rock is defined as an aggregate of one or more minerals that have been brought together into cohesive solid [1]. The principal factors controlling the strength of solid rocks are density and porosity [2]. Architects and Geoscientist used the knowledge of density in the design of bridges, flyovers and other structure [3]. Density is a fundamental concept in sciences, it is used quite often in identifying rocks and minerals since density of a substance rarely changes significantly. Density is mass per unit volume for a substance and this is true for all materials. While the definition is straight forward, to calculate the accurate and reliable value for the density of a material can be difficult to achieve in some circumstances. For example, objects that consist of irregular shapes, highly fractured and made up of many pieces can cause difficulties in determining an accurate volume and thus the density. In most cases, to determine the mass of an object is easy, but the volume is difficult, which poses a significant challenge in obtaining an accurate density [4]. Porosity can be expressed either as a fraction or as a percentage. It should be noted that the porosity does not give any information concerning pore sizes, their distribution, and their degree of connectivity. Thus, rocks of the same porosity can have widely different physical properties. Porosity is affected by three major microstructural parameters. These are grain size, grain packing, particle shape, and the distribution of grain sizes. Porosity is a function of the seasonal or spatial variability of bulk density, or the scale of the bulk density measurement, whether clod scale or irregular hole determinations of various sizes, or surface or borehole geophysical or acoustical techniques on quite large scales [5]. The porosity is conventionally given the symbol Φ, and is expressed either as a fraction varying between 0 and 1, or a percentage varying between 0% and 100%. Sometimes porosity is expressed in 'porosity units', which are the same as percent (i.e., 100 porosity units (pu = 100%). Porosity is a ratio of the volume of the pores to the total volume of the particle. Permeability refers to the particle's ability to allow liquids to pass through. If the rock pores are not connected, a rock may have high porosity and low permeability. The diagnostic properties of some common minerals and rocks and the intrinsic properties controlling rock strength, which include density and porosity; they are important variables used in investigating all the rock forming minerals [6]. When accurately calculated, densities of rock is essential in Petrological and geological studies and more so for a meaningful structural interpretation of gravity anomalies [7].

The Jos-Plateau is an area of Younger Granites, which was intruded through an area of Older Granite making up the surrounding state. These Younger Granites are about 160 million years old, these creates the unusual scenery of the Jos-Plateau. There are numerous hillocks with gentle slopes emerging from the ground like mushrooms scattered with huge boulders. The phases of volcanic activities in the formation of Plateau state, this have made Jos-Plateau one of the mineral rich state in the country, Tin and other minerals are still mined and processed locally in the state. Acceleration due to gravity is always assumed to range between 9.8 - 10 ms^{-2}, one of the underlying reason is because of variation of density around the surface of the earth since the surface of the earth is not smooth, non-uniform and inhomogeneous. In sedimentary rocks, density increases with age and depth, that is compaction and cementation. While in igneous rocks, density increases with basicity so granites tend to have low density and basalt high density. Anticlines can also give gravity anomalies as they cause high or low-density bed to be brought closer to the surface.Researchers usually neglect establishing a relationship between particle density and porosity possibly dueto the fact that it is time and energy consuming and involve very low values that seem irrelevant, but very smallchange in these values can lead to significant changes in the mechanical strength due to variation in the UniaxialCompressive Strength (UCS) [8]. Thus, it might result in the destruction of the engineeringdesign leading to loss of lives and property. The correlation of density and porosity as well as performingconfirmatory test on the rocks will possibly help in solving this problem [9]. Correlation is the process of determining the dependence of one variable on another, hence this research work seek to determine the correlation i.e. the dependence of dry density on porosity or vice visa of rock samples in Jos and environs, Plateau state Nigeria.The aim of this research work is to determine the Correlation between dryDensity and Porosity of rock samples in Jos and its environs. The following are objectives of the study; to take the coordinate and mass of each rocks sample on the field; to determine the dry density and porosity of the rock samples in the laboratory; to carry out Petrography Study to determine rock type; to determine the correlation between dry density and porosity of each rock type.

II. SIGNIFICANCE OF STUDY

It has been established that the density of a material or a substance does not change no matter the size, except there exist another material(s) in it, hence the density will change, and the new density will explain in details the amount or the quantity of the other material(s) in it. “A knowledge of the density of a rock is essential in Petrological and Geological studies and more so, for any meaning structural interpretation of gravity anomalies” [7].

III. GEOLOGY OF THE STUDY AREA

Naraguta Area lies in the North Central part of Nigeria on Naraguta sheet 168, comprising areas around Jos and its surrounding towns such as Bukuru, Rukuba, Foron, Miango, Kigom, Ganawuri, Kagoro, Vom. The area lies within the Northern Guinea Savannah vegetation zone which is an open wood land with tall grasses, shrubs and stunted trees. Throughout the area, there is a close relationship between rock type and scenery [9]. The rock types found in the area are; Jos Biotite Granite, Rukuba Biotite Granite, Neil Valley Granite Porphyry, Hornblende Biotite Granite, Aegerine, Naraguta quartz, Naraguta Diorites, Migmatites, Undifferentiated Migmatites and others. Volcanic activities which occurred several years ago, created vast basaltic plateau and volcanoes, producing regions of mainly narrow and deep valleys, and sediments from the middle of rounded hills with shear faces. However, it seems likely that emplacement of the Younger Granites was associated with Epeirogeric uplift. Indirect evidence for this is lack of sediments associated with the volcanic rocks of the Younger Granites age, which are apparently erupted on to land surface undergoing erosion, not deposition [10]. This research work is limited to an area of 239.031 square kilometers, covering Jos central, Mile 9 (NEPA), Yelwa; Rukuba, FarinGada; Maza, Gwafan, Dustin JebuBassa and Naraguta village and the types of rocks found there.

IV. LOCATION AND SETTING

The study area is covering Jos central, Mile 9 (NEPA); Yelwa; Rukuba, FarinGada; Maza, Gwafan, Dustin, JebuBassa and Naraguta village. The work covers the length of 27.00 km and a breath of 8.85 km giving a total area of 239.031 square kilometers within the

Naraguta sheet 168 in the Jos-Plateau, a mountainous area in the north-central Nigeria with captivating rock formation, bare rocks are scattered across the grassland. The area is bounded by Latitude 9^{o} 55' 00.00"N - 10° 00' 00.00"N and Longitude 8° 45' 00.00" E - 9° 00' 00" E. Fig 3 shows the Satellite Map of the study area. **Fig. 1** shows the location of the study area on the map of Nigeria and **Fig. 2** shows Digitized Geology map of Study area and the rock types.

Figure 1: Location of study area in Nigeria

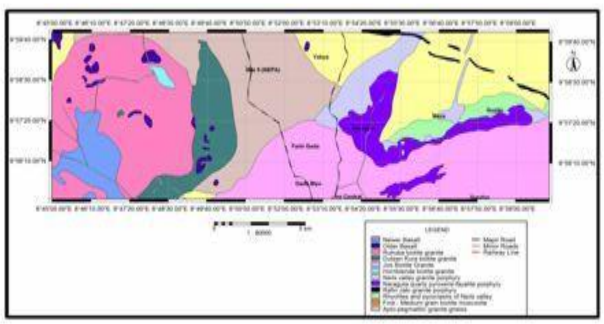

Figure 2: Digitized Geology map of Study area (Extracted from Geological Map of Naraguta Sheet 168. Compiled and Published by the Geological Survey of Nigeria, 1963)

V. METHODS AND MATERIALS

TheField Materials and Instruments used are: - Handheld Garmin GPS device, a Compass, Geo-Hammer and chisel; Meter Tape; Geological notebook and others. Laboratory Materials and Instruments are: - Measuring cylinder 50ml and Density bottle 10ml, Adam Electronic Weighing Scale, Archimedes' Principle setup, Eureka Can. The Petrography Materials and Instruments: - Polarized Microscope, Glass Slides and abrasive and GTS1 Thin Section machine cut-off and trim saw. The methods used were the in situ method by [12] and [13] to determine density a total of 80 samples were collected and in laboratory after the measurement, the following values of Dry density, Particle density, and Porosity were calculated. The method used covered the procedure for determining the porosity and the dry density of a rock sample in the form of lumps of irregular shape and was used for rocks that do not appreciably disintegrate when dried or swell when immersed in water. For non-porous samples, the easiest way to measure the density of material is to weigh it in air and then in water assuming, the water is pure at 25°C.

Dry density

To determine the Dry density of the sample, the rock samples were dried for 8 hours in an oven; then the mass in air was recorded as $\mathbf{dM_a}$and the same sample was placed on a thread loop, then immersed in water and the reading was quickly taken and recorded as $\mathbf{dM_w}$. This procedure was repeated for all other dried rock samples.

$$\textbf{Dry Density } (\rho d) = \frac{dM_a}{dM_a - dM\omega} \quad \textbf{(1)}$$

Where: $\mathbf{dM_a}$= Mass of rock in air and $\mathbf{dM_w}$= Mass of rock sample in water.

Particle (Grain) Density.

To determine the particle density, the samples were soaked for 24 hours in a container filled with water to ensure that the pores spaces are completely filled or saturated with water. The soaked sample was quickly transferred from the bath of water to a basket and weight in air as $W\mathbf{M_a}$ was taken and then placed on the loop then immersed in water in the bucket and the reading were taken quickly, recorded as $W\mathbf{M_w}$**.** This procedure was repeated for all other soaked rock samples. The formula below is used.

Particle or Grain Density,

$$(\rho \textbf{ particle}) = \frac{WM_a}{WM_a - WM_w} (2)$$

Where: $W\mathbf{M_a}$= Wet Mass of rock in air and $\mathbf{WM_w}$= Wet Mass of rock sample in water.

Porosity

The sample porosity (Φ) was determined as the percentage of one minus the ratio of dry density to particle density (Baiyegunhi, el 'al, 2014). Figure 4 Digitized Geology map of Sample distributions in the study area.

$$\textbf{Porosity} \quad \Phi = [1 - \frac{\text{Dry density}}{\text{Particle density}}] \times 100 \quad \textbf{(3)}$$

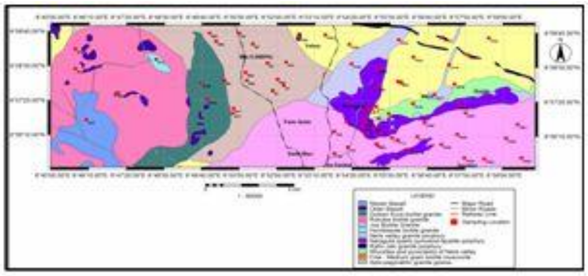

Figure 3: Digitized Geology map of Sample Location (Extracted from Geological Map of Naraguta Sheet 168. Compiled and Published by the Geological Survey of Nigeria, 1963.

VI. RESULTS/ANALYSIS AND DISCUSSION

The results for some of the field and laboratory measurement are presented in table1 and table 2 **Some Laboratory Measurement of Samples. The** mean **Dry density and porosity were calculated from the** values of Dry Density, Particle Density and Porosity for various Rock types are presented in table 3.and Table 4 shows the correlation between Dry Density and Porosity for each rock. Table 5 shows the interpretation of the values of the correlation coefficients for all the rock types in the study area. Fig.5a-5i shows the graph of porosity against Dry Density and the line of best fit.

Table 1: Some Field Measurements

Sample id.	Coordinate	Rock Description/ Area	Mass in the field (g)
J1	Lat.09°56' 4.7"	Aegerine Granite	1576
	Lon. 8°54' 6.7"	Odus	
	Elev. 1210m		
J2	Lat. 09°57' 0.4"	Aegerine Granite	1890
	Lon: 8°54' 2.9"	Odus	
	Elev. 1205m		
J3	Lat. 09°57'5.1"	Biotite Granite	1274
	Lon: 8° 53'6.5"	Main camp	
	Elev. 1181m		
J4a	Lat. 09°58'23.4"	Quartzite	1191
	Lon:8°53' 3.3"	village hostel	
	Elev. 1123m		
J4b	Lat. 09° 58' 23.4"	Quartzite	1173
	Lon:8° 53' 13.3"	village hostel	
	Elev. 1123m		
J4c	Lat.09° 58' 23.4"	Quartzite	536
	Lon:8° 53' 09.6"	village hostel	
	Elev. 1118m		

Table 2: Some Laboratory Measurement of Samples

Sample ID.	Mass in Air (g)	Mass in Water (g)	Saturated Mass in Air (g)	Saturated Mass in Water (g)
J1	1614	1030	1633	1011
J2	1940	1204	1947	1209
J3	1323	801	1345	814
J4a	1242	758	1259	762
J4b	1219	744	1231	750
J4c	592	358	603	361
J4d	1554	949	1566	932
J5a	1953	1279	1962	1284
J5b	1127	729	1137	743
J5c	1485	979	667	987

Table 3: Mean Dry Density and porosity

Rock	Density (g/cm³)	Porosity (%)	Sample No.
Rukuba Granite Gneiss	2.609	1.494	2
Diorites	2.888	0.480	3
Older Basalt	2.942	0.356	2
Aegerine	2.663	1.831	9
Naraguta Quartzite	2.615	1.469	11
Jos Biotite granite	2.578	1.880	19
Migmatite	2.643	1.617	7
Neil valley Granite Porphyry	2.638	2.164	7
Hornblende Biotite granite	2.579	1.826	18
Rhyolite	2.623	0.753	2

Table 4: The Correlation of density and porosity for each rock sample.

Rock	Correlation
Rukuba Granite Gneiss	-1.0000
Basalt	-1.0000
Neil valley Granite Porphyry	-0.8362
Hornblende Biotite granite	-0.2909
Naraguta Quartzite	-0.2386
Jos Biotite granite	-0.0784
Aegerine	-0.0662
Migmatite	0.07997
Diorites	0.36304
Rhyolite	1.00000

Linear relationship betweenporosity and dry density

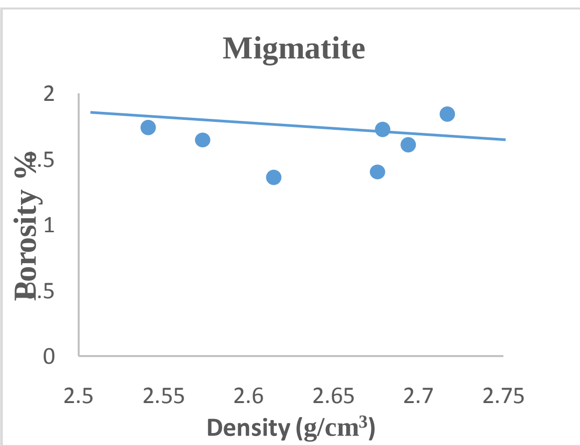

Figure5a: Migmatite

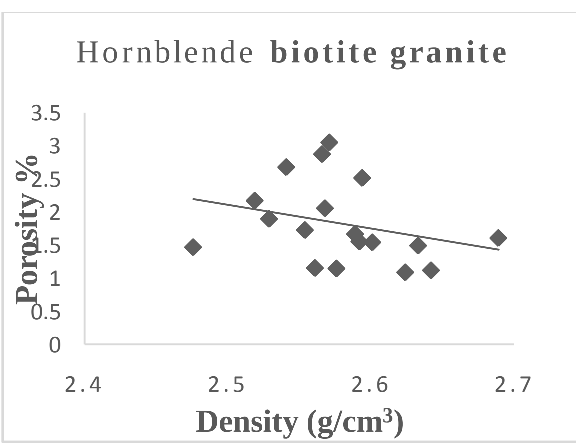

Figure 5b: Hornblende Biotite granite

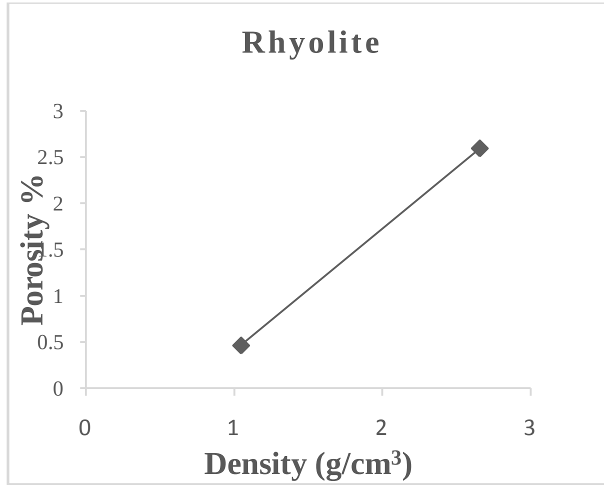

Figure 5c: Rhyolite

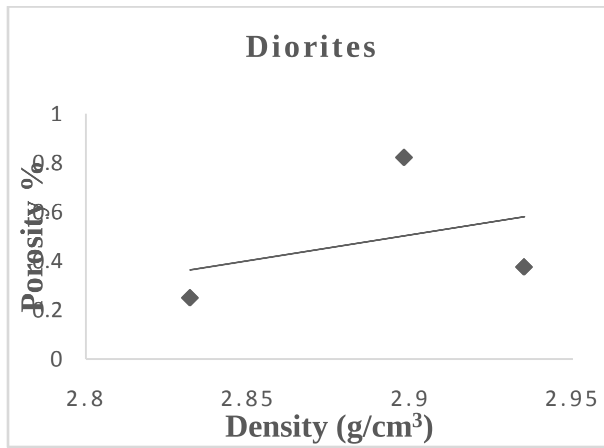

Figure 5d: Diorite

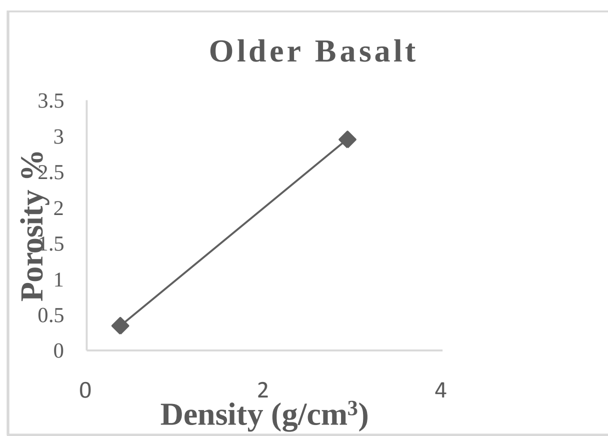

Figure 5e: Older Basalt

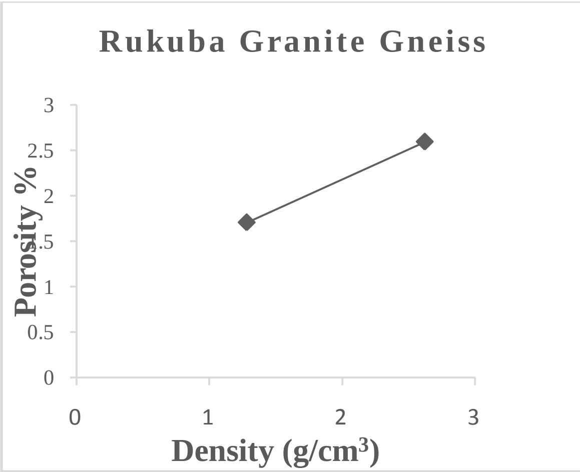

Figure 5f: Rukuba Granite Gniess

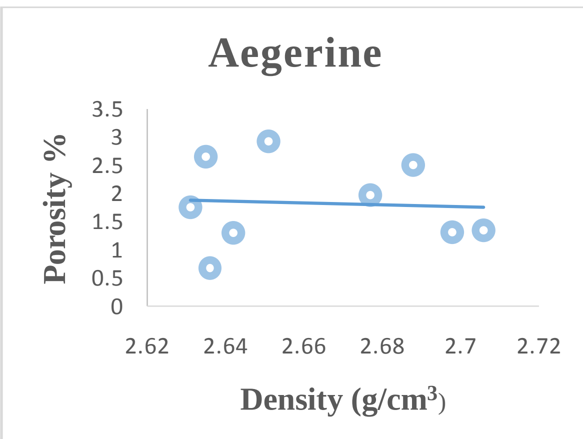

Figure 5g: Aegerine

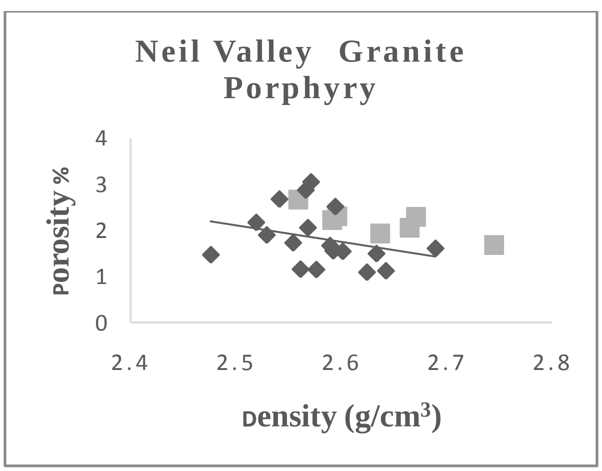

Figure 5h:Neil Valley Granite Porphyry

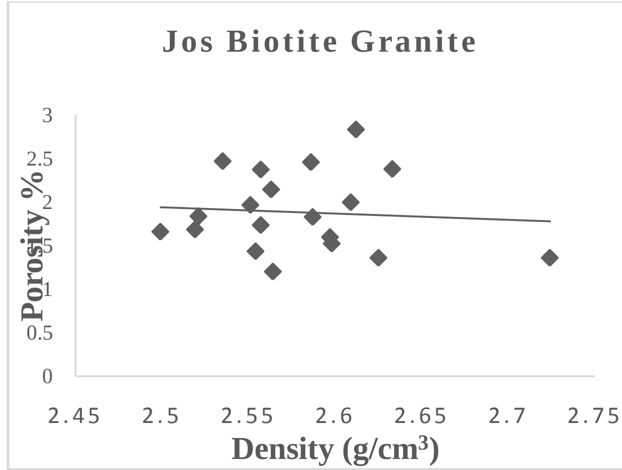

Figure 5i: Jos Biotite Granite

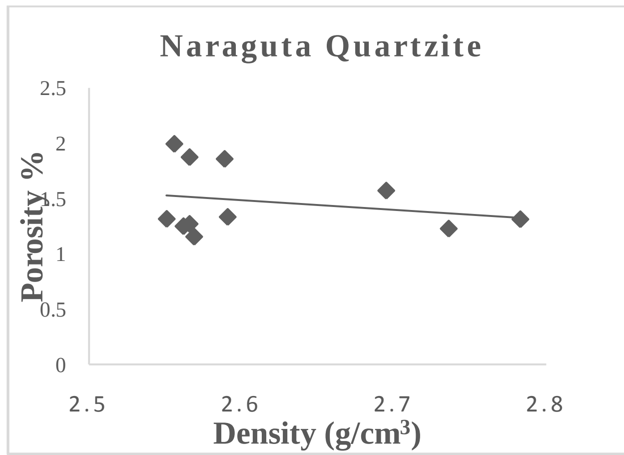

Figure 5j: Naraguta Quartzite

Table 5: Interpretation of the Correlation Values

Location	Correlation	Linear Relationship
Rukuba Granite Gneiss	-1.0000	Perfectly related
Older Basalt	-1.0000	Perfectly related
Neil valley Granite Porphyry	-0.8362	Strongly related
Hornblende Biotite granite	-0.2909	Weakly related
Naraguta Quartzite	-0.2386	Weakly related
Jos Biotite granite	-0.0784	Not related
Aegerine	-0.0662	Not related

Migmatite	0.07997	Not related
Diorites	0.36304	Weakly related
Rhyolite	1.0000	Perfectly related

CONCLUSION

Correlation coefficient was employed to predict the relationship between the porosity and density of the rock samples. For Rukuba Granite Gniess and Older Basalt (-1) shows that the porosity and density are perfectly related negatively. For Neil Valley Granite Porphyry, there is a strong negative relationship (-0.8362) between porosity and density, but for Hornblende Biotite granite and Naraguta Quartzite shows a weak negative relationship (-0.2909 and -0.2386 respectively). Jos Biotite Granite, Aegerine and Migmatite the porosity and density are not related; Diorite shows a weakly related correlation of 0.36304 and lastly, Rhyolite shows a perfectly related correlation of +1. Those rocks that have perfect correlation should be consider mostly in construction works to increase the strength of the structure.

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