INTERNATIONAL JOURNAL OF NATURAL AND APPLIED SCIENCES (IJNAS) VOL. 2, NO. 2: P. 127 – 133, 3 TABLES, 5 FIGS.

Determination of density and porosity of rock units in Afikpo area, south of the Benue trough, Nigeria

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ABSTRACT

Over 200 rock samples representing the major sedimentary, metamorphic and igneous rock units in Afikpo area were collected and various laboratory tests were carried out on them in order to determine their densities and porosities. The objectives are to provide reference materials to researchers who may run gravity traverses within this area and also to intimate hydrogeologists about the aquifereous units within this study area. The results obtained are quite comparable with results of similar rock types from other places like England and (New Zealand). The lowest density of 2.27g/cm^3 has been calculated for Uwana siltstone while the highest value of 3.23g/cm^3 is obtained for the dolerite sill. The porosity range is from 0.03 to 0.11 with the Afikpo sandstone and siltstone having the highest. These results would be valuable materials in gravity data analysis where density contrast of these rock units are needed. Also in groundwater exploration, rocks with high porosities should be the targets

INTRODUCTION

Afikpo area is at the southern Nigeria at the southeastern part of the Benue trough, generally referred to as the Afikpo syncline, fig. 1. It is bounded by Latitudes 5^{0}50´ – 5^{0}55´N and Longitudes 7^{0}50´ – 7^{0}55´E. The area is characterized by interesting geological features including massive sandstone with planar – tabular cross bedding, intermediate intrusives and limestone deposit.

Rock density has particular value as a theme that connects the properties of minerals and rocks to topics such as Seismic Velocity, Isostasy and Porosity (Robert and Robert, 2000). Knowledge of densities of the rocks is essential in petrological and geological studies and more so for a meaningful structural interpretation of gravity anomalies (Ajakaiye, 1975). Hung et al, 2000, also stated that the gravity reduction is computed by taking the density as a constant, 2.67g/cm^3, which represents the mean topographical density. The present study is a pioneering research on rock samples from the Afikpo. The results would be useful in any future work on gravity and tectonics and would also serve as a valuable guide in groundwater exploration.

Geology of the study area

The Afikpo area is underlain by cretaceous sedimentary rocks of Ezeaku Formation which has three major sandstone members viz: Afikpo sandstone, Amaseri sandstone and Owutu sandstone,
(figure 2).

During the Albian times (i.e Asu River Group; it comprises of Abakaliki shale), marine transgression deposited shales in the area (Peters and Ekweozor, 1982).

The end of the Albian witnessed the beginning of the regressive phase which continued into Cenomanian. During the Turonian, the sea again covered large areas of the Afikpo syncline when it laid down the rocks of the Ezeaku Formation, (Short and Stauble, 1967)
During the Coniacian (Awgu shale), beds of rapidly changing lithofacies including shale were deposited. The rapid facies change has been interpreted by Short and Stauble (1967) as being the first indication of the active tectonic phase of folding, faulting and uplifting which ended during the Santonian. The Santonian movements resulted in the folding, uplifting and faulting of the Abakaliki anticlinorium (fig.1) which in turn led to the exposure and subsequent erosion of the Coniacian, Turonian and Albian Formations. Consequent to this uplift, two depressions were formed flanking the Abakaliki anticlinoruim; the wide Anambra basin to the north west and the narrow Afikpo syncline to the south east. A summary of the stratigraphy of the cretaceous column in southern Benue is shown in table 1.

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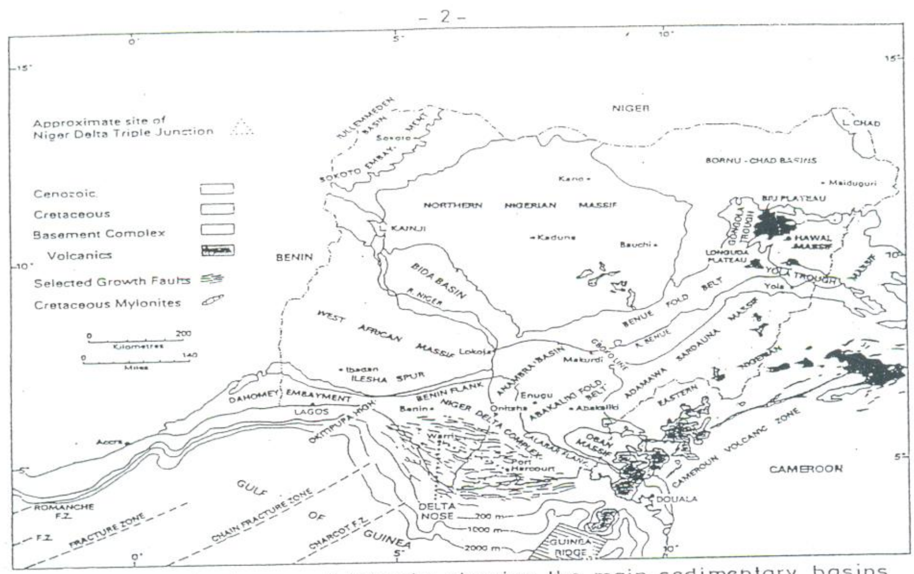


FIG. 1· Geological map of Nigeria showing the main sedimentary basins and some growth fault (Adapted from Whiteman, 1982)

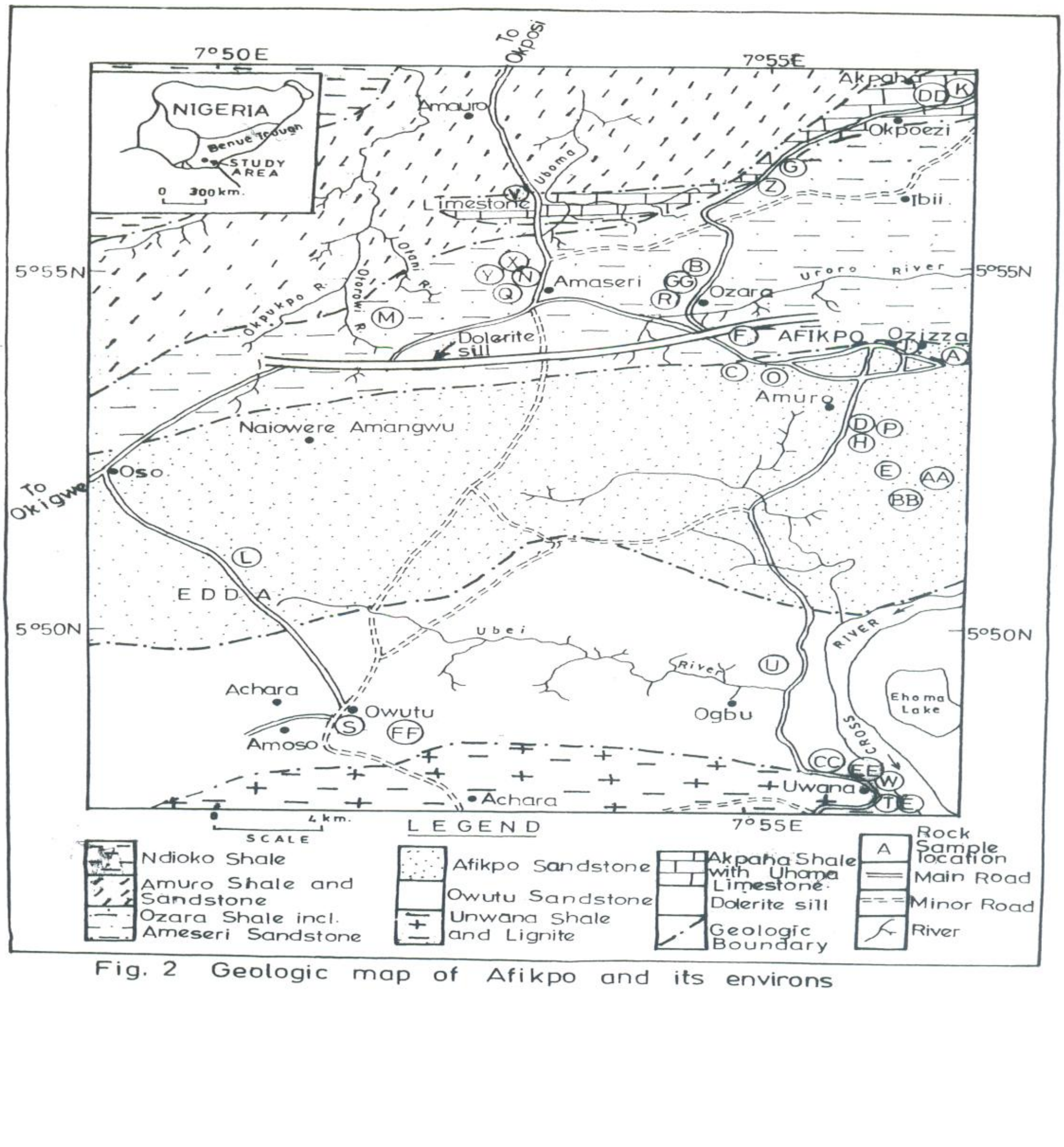


Fig. 2 Geologic map of Afikpo and its environs

Table 1. Cretaceous sedimentary sequence in the South Benue Trough, Reyment, 1965

	PERIOD		FORMATION
	Maestrichian		Nsukka Formation
Upper Creataceous	Senonian	Campanian	Ajali Formation
		Santonian Coniacian	Mamu Formation Nkporo Shales Awgu Shale
	Taronian		Markurdi Formation
	Cenomainian		Ezeaku Shales
Lower Cretaceous	Albian		Asu River Group

MATERIALS AND METHODS

Rock samples were collected from many locations shown in figure 2 using tarred and untarred roads and footpaths. The collection which covered the major lithofacies were labeled A to Z and AA to GG, (figure 2).

Parasnis (1952) in a study of rock density emphasized that the "field" density of a rock must lie between the dry and the saturated densities. This is because the amount of water present in a rock in-situ is unknown. Parasnis accepted the saturated density as being the best approximation to the "field" density (Gibb. 1968). In sedimentary rocks, the difference between the dry and saturated densities is often negligible. Rock texture plays a very important part because the petrophysical properties of a sedimentary rock such as porosity and permeability, depend essentially on texture (Al-Homadhi and Hamado, 2001).

About 200 rock samples were taken to the laboratory for analysis. They were heated in an oven at a temperature of 100^oC for 18 hours and later weighed separately in air (W_d) and in water (W_w) using a lever balance. The samples were then saturated in water for 24 hours and weighed again in water (W_s) and in air (W_t). From these results, the dry bulk density ℓ_d, saturated density ℓ_s, particle or grain density ℓ_g and porosity Ø were deducted using the following mathematical expressions (Ajakaiye, 1975):

Dry bulk density, $$\ell_d = \frac{W_d}{W_t - W_s} \quad (1)$$

Saturated density, $$\ell_s = \frac{W_t}{W_t - W_s} \quad (2)$$

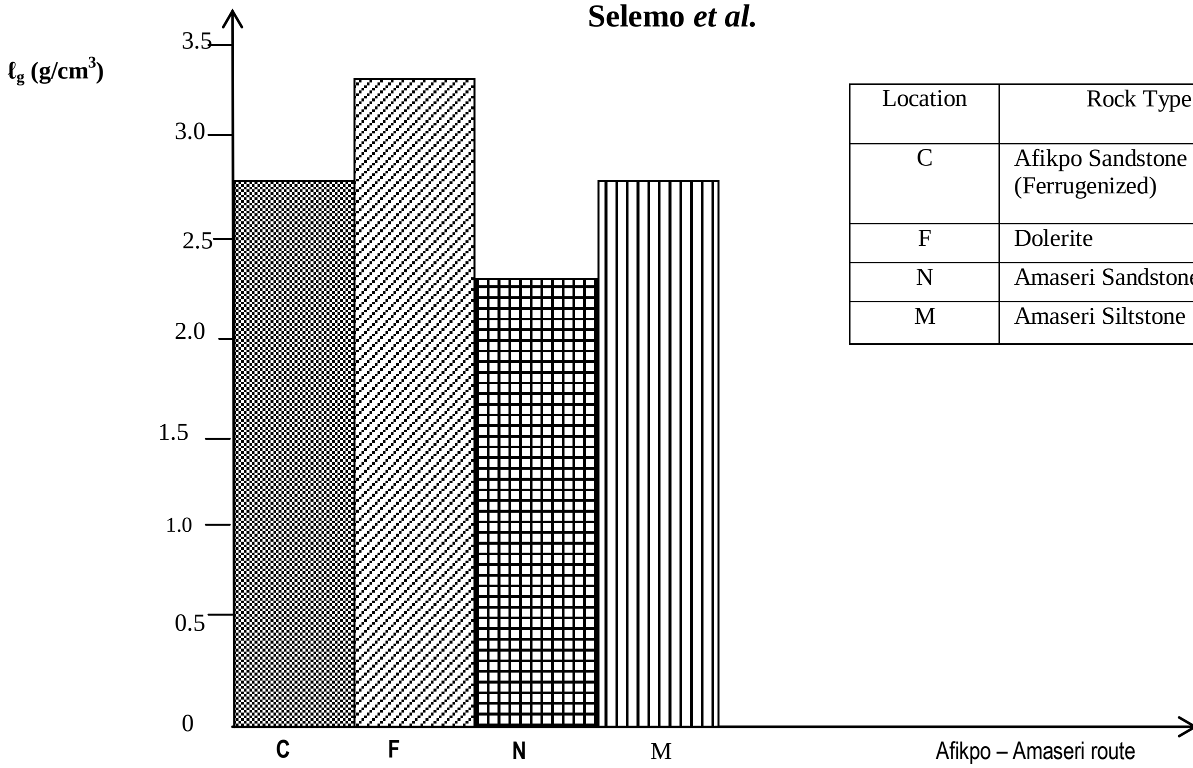
Particle or grain density $$\ell_g = \frac{W_d}{W_d - W_s} \quad (3)$$

Porosity $$Ø = \frac{Ws - W_w}{W_d - W_w} \quad (4)$$

The results for the various rock types are shown in table 2.

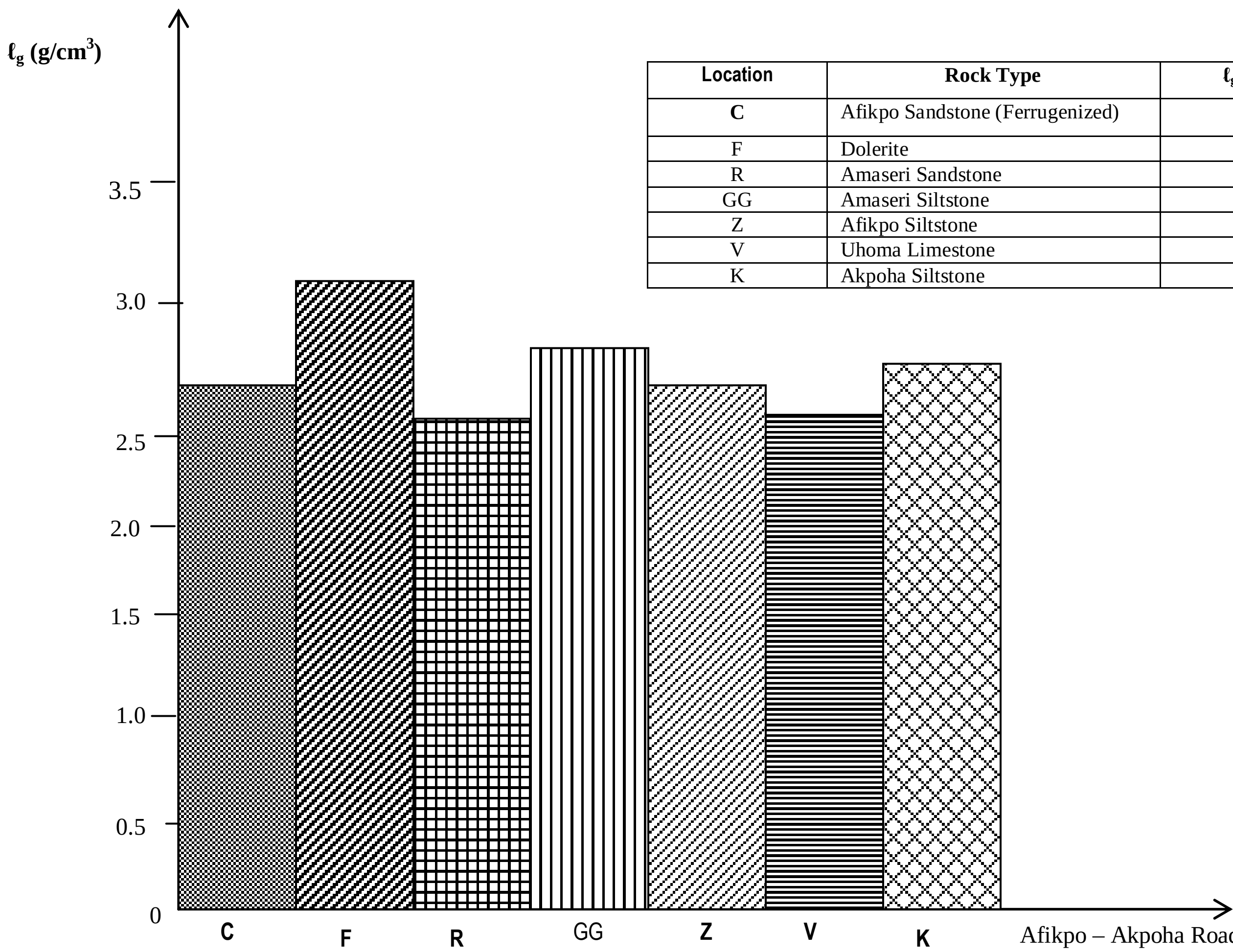
RESULTS AND DISCUSSION

Table 3 gives a comprehensive summary of the results of all the laboratory tests and calculations made on all the rock samples. Figures 3 – 5 are histograms showing grain density of various rock types. Figure 3 is the result for Afikpo – Amaseri route while figure 4 is that for Afikpo – Akpoha. It can be observed that the dolerite sample has the highest density (3.19g/cm^3) along this axis. The histogram for Afikpo / Uwana route is displayed in figure 5. The density of samples from each rock unit along this axis differs from each other slightly: this could probably be due to variation in mineral contents and other physical factors like weathering etc. Hence for each rock type the densities are presented as a range or a mean value. Consequently, the mean densities which are representative of the rock units are shown in Table 2. These results are quite comparable with densities of the same rock units from England and New Zealand (also cretaceous) as shown in Table 3.



Location	Rock Type	ℓ_g (g/cm^3
C	Afikpo Sandstone (Ferrugenized)	2.76
F	Dolerite	3.23
N	Amaseri Sandstone	2.62
M	Amaseri Siltstone	2.80

Fig. 3 .Histogram of grain density along Afikpo – Amaseri Route



Location	Rock Type	ℓ_g (g/cm^3
C	Afikpo Sandstone (Ferrugenized)	2.76
F	Dolerite	3.23
R	Amaseri Sandstone	2.62
GG	Amaseri Siltstone	2.80
Z	Afikpo Siltstone	2.71
V	Uhoma Limestone	2.69
K	Akpoha Siltstone	2.74

Fig. 4. Histogram of grain density along Afikpo – Akpoha Route

Density and porosity of rock units

Location	Rock Type	ℓ_g (g/cm^3
O	Afikpo Sandstone (Ferrugenized)	2.76
H	Afikpo Siltstone	2.71
U	Owutu Sandstone	2.51
W	Uwana Sandstone	3.13
T	Uwana Siltstone	2.36

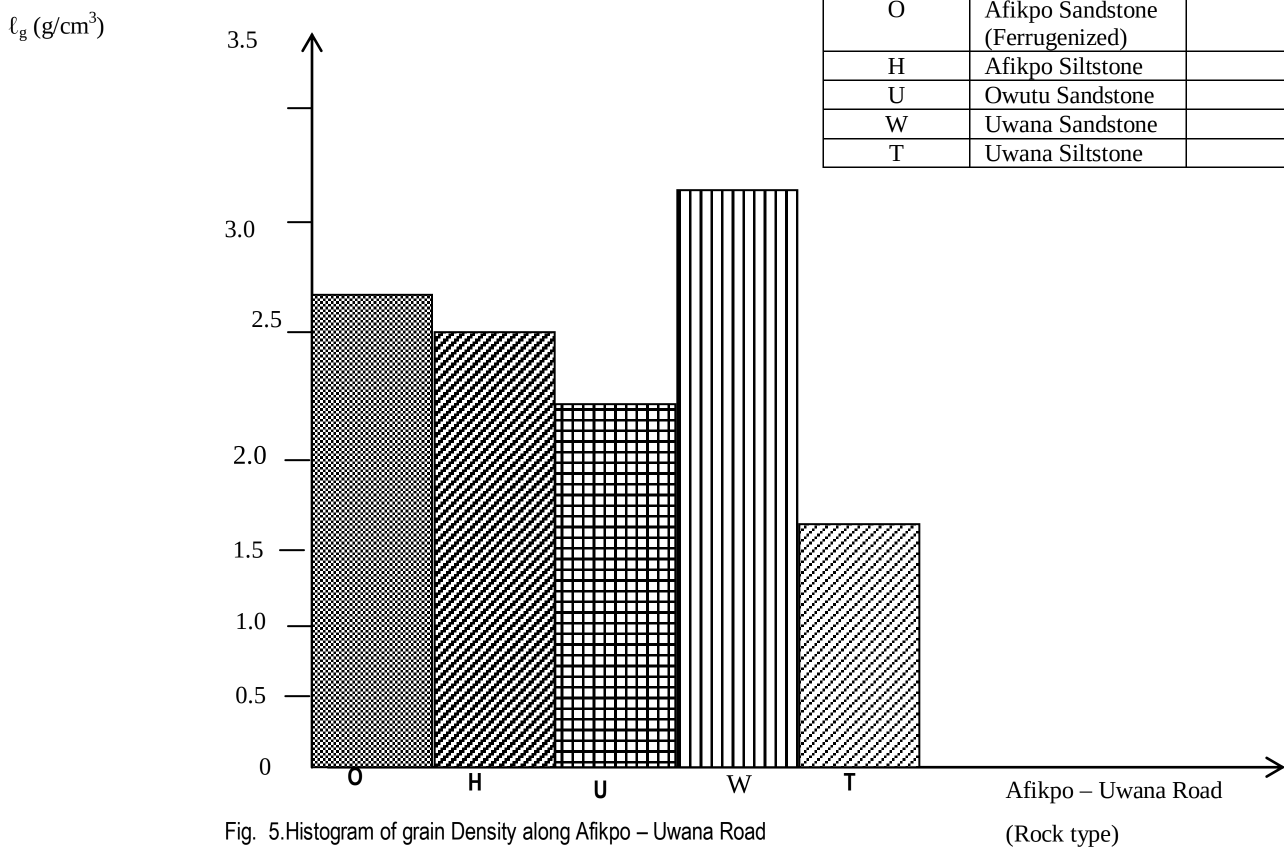


Fig. 5.Histogram of grain Density along Afikpo – Uwana Road

Table 2. Summary of the results of rock densities and porosities.

S/N	Sample	* ℓ_s (g/cm^3)	** ℓ_g (g/cm^3)	Ø Porosity
1.	Afikpo Sandstone	2.59	2.76	0.10
2.	Afikpo Sandstone (Ferrugenized)	2.49	2.75	0.11
3.	Amaseri Sandstone	2.44	2.62	0.08
4.	Owutu Sandstone	2.37	2.51	0.10
5.	Owutu Sandstone (Conglomerata)	2.34	2.42	0.08
6.	Uwana Siltstone	2.27	2.36	0.09
7.	Uwana Sandstone	2.84	3.13	0.07
8.	Akpoha Siltstone	2.57	2.74	0.05
9.	Afikpo Siltstone	2.67	2.71	0.11
10.	Amaseri Siltstone	2.75	2.80	0.04
11.	Dolerite	3.19	3.23	0.02
12.	Uhoma Limestone	2.61	2.69	0.07

* ℓ_s = saturated density ** ℓ_g = grain density

Table 3. Comparison of mean values of saturated density (ℓ_s) and grain density (ℓ_g) of rocks of the Afikpo area with those of England and New Zealand.

Densities are in g/cm^3

	Afikpo		Amaseri		Owutu		Uwana		Akpoha		Uhoma		ENGLISH MIDLANDS {Parasnis 1952}		NEW ZEALAND {Hatherton & Leopard 1964}	
	ℓ_s	ℓ_g	ℓ_s	ℓ_g	ℓ_s	ℓ_g	ℓ_s	ℓ_g	ℓ_s	ℓ_g	ℓ_s	ℓ_g	ℓ_s	ℓ_g	ℓ_s	ℓ_g
Sandstone	2.59	2.76	2.44	2.62	2.37	2.51	2.84	3.13	-	-	-	-	2.43	2.70	2.58	2.63
Siltstone	2.67	2.71	2.75	2.80	-	-	2.27	2.36	2.57	2.74	-	-	2.62	2.72	2.53	2.63
Limestone	-	-	-	-	-	-	-	-	-	-	2.61	2.69	2.65	2.72	-	-

Porosity is another important physical parameter determined in this study. The mean porosity for each rock type is also included in Table 2. It can be observed that Afikpo sandstone and Afikpo siltstone have the highest porosity (0.11). This is followed by Owutu sandstone (0.10). The least porous rock unit is the Dolerite which has a value of 0.03.

CONCLUSION

This work has opened a new frontier for other research studies in Afikpo and its environs. The results of this work would give valuable information for studies on gravity where densities of the rock units could be used in modeling Bouguer anomalies. In geotechnical studies, porosity of rock units are usually determined before any structural design is considered. Finally, for groundwater exploration, rock units with high porosity should be the targets.

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