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Density and Magnetic Susceptibility Characterization in the Basement Complex Terrain of NE Kogi State/NW Benue State of Nigeria

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Abstract: ***Thirty one rock samples were collected and analysed in the laboratory using spring balance to determine the densities of rocks of the Kogi-Benue NW basement complex area which has extensive lithologic variation. The dry bulk and saturated densities of the various samples were determined. The sedimentary rocks which were dominantly sandstones had values that ranged from 1.85gm/cm^3 to 2.35gm/cm^3 with a slight drop also between the dry bulk and saturated density. The saturated density of the sedimentary rocks was almost consistently greater than the dry bulk density by 0.008gm/cm^3. Gabbro rock samples were taken as representative of the igneous rocks which in the measurement indicated high density values and appreciable content of magnetic elements. The dry bulk density of the metamorphic rocks ranged from 2.33gm/cm^3 to 2.77gm/cm^3 with a slight difference of 0.41gm/cm^3 and dominated by schists while the igneous rocks ranged from 2.34gm/cm^3 to 2.73gm/cm^3 with no significant difference between the dry bulk and saturated densities. Magnetic susceptibility measurements were carried out to aid interpretation of the magnetic data and it shows a magnitude of 0.0001 to 0.00015emu ranged and from available data, it is probable that Cordierite-Tourmaline schist with a magnetic susceptibility value of 0.00015emu is higher than other metamorphic rocks in the area. The magnetic susceptibility of the gabbro igneous rock was more prominent than those of sedimentary sandstone and metamorphic rocks schists and gneisses.***

Keywords: Dry bulk density, saturated density, magnetic elements, magnetic susceptibility, lithologic variation

1. Introduction

Density and magnetic susceptibility are relevant characteristics of rocks that gravity and magnetic studies utilize respective characteristic sensitivities on these potential field studies with the particular physical property adopted in the investigation. For this purpose, thirty one rock samples collected during the field survey, were analysed in the laboratory using spring balance to determine the approximate densities of surface Basement complex rocks (Rahaman, 1976) of the study area which have a wide range of lithologic variation (Adeleye, 1976). The dry bulk and saturated densities of the various samples were determined. The sedimentary rocks which were dominantly sandstones ranged from 1.85gm/cm^3 to 2.35gm/cm^3 with a slight drop also between the dry bulk and saturated density. The saturated density of the sedimentary rocks was almost consistently greater than the dry bulk density by 0.008gm/cm^3. Gabbro rock samples were taken as representative of the igneous rocks which in the measurement indicated high density values (Ajakaiye, 1976) and appreciable content of magnetic elements.

The dry bulk density of the metamorphic rocks ranged from 2.33gm/cm^3 to 2.77gm/cm^3 with a slight difference of 0.41gm/cm^3 and dominated by schists (Ojo and Ajakaiye, 1976). while the igneous rocks ranged from 2.34gm/cm^3 to 2.73gm/cm^3 with no significant difference between the dry bulk and saturated densities.

Magnetic susceptibility measurements were carried out to aid interpretation of the magnetic data and it shows a magnitude of 0.0001 to 0.00015emu ranged and from available data, it is probable that Cordierite-Tourmaline schist with a magnetic susceptibility value of 0.00015emu is higher than other metamorphic rocks in the area.

2. Objective of Study

The study was aimed to reveal any pattern of distribution of densities and magnetic susceptibility of the major rock types in the Basement Complex terrain of the part of middle Benue trough, covering NE Kogi and NW Benue States of Nigeria.

Geologic Setting of Benue Trough

The Benue Trough of Nigeria is a rift basin in central West Africa that extends NNE–SSW for about 800 km in length and 150 km in width. The southern limit is the northern boundary of the Niger Delta, while the northern limit is the southern boundary of the Chad Basin (Obaje 2009). The trough contains up to 6,000 m of Cretaceous – Tertiary sediments of which those predating the mid-Santonian have been compressionally folded, faulted, and uplifted in several places. Compressional folding during the mid-Santonian tectonic episode affected the whole of the Benue Trough and was quite intense, producing over 100 anticlines and synclines (Benkhelil, 1989). Major such deformational structures include the Abakaliki anticlinorium and the Afikpo syncline in the Lower Benue, the Giza anticline and the Obi syncline in the Middle Benue, and the Lamurde anticline and the Dadiya syncline in the Upper Benue Trough. Following mid-Santonian tectonism and magmatism, depositional axis in the Benue Trough was displaced westward resulting in subsidence of the Anambra Basin. The Anambra Basin, therefore, is a part of the Lower Benue Trough containing post-deformational sediments of Campanian-Maastrichtian to Eocene ages. It is logical to include the Anambra Basin in the Benue Trough, being a related structure that developed after the compressional stage (Akande and Erdtmann, 1998). The Benue Trough is arbitrarily subdivided into a lower, middle and upper portion but no concrete line of subdivision can be drawn to demarcate the individual portions, though major localities (towns/settlements) that constitute the depocentres of the different portions have been well documented (Nwajide, 1990; Obaje et al., 1999). The depocentres of the Lower Benue Trough comprise mainly the areas around Nkalagu and Abakaliki, while those of the Anambra Basin centre around Enugu, Awka and Okigwe. The Middle Benue Trough comprises the areas from Makurdi through Yandev, Lafia, Obi, Jangwa to Wukari. In the Upper Benue Trough, the depocenters comprise Pindiga, Gombe, Nafada, Ashaka (in the Gongola Arm) and Bambam, Tula, Jessu, Lakun, and Numan in the Yola arm.

Sedimentation in the Lower Benue Trough commenced with the marine Albian Asu River Group, although some pyroclastics of Aptian – Early Albian ages have been sparingly reported (Ojoh, 1992). The Asu River Group in the Lower Benue Trough comprises the shales, limestones and sandstone lenses of the Abakaliki Formation in the Abakaliki area and the Mfamosing Limestone in the Calabar Flank (Petters, 1982). The marine Cenomanian – Turonian Nkalagu Formation (black shales, limestones and siltsones) and the interfingering regressive sandstones of the Agala and Agbani Formations rest on the Asu River Group. Mid-Santonian deformation in the Benue Trough displaced the major depositional axis westward which led to the formation of the Anambra Basin. Post-deformational sedimentation in the Lower Benue Trough, therefore, constitutes the Anambra Basin. Sedimentation in the Anambra Basin thus commenced with the Campanian-Maastrichtian marine and paralic shales of the Enugu and Nkporo Formations, overlain by the coal measures of the Mamu Formation. The fluviodeltaic sandstones of the Ajali and Owelli Formations lie on the Mamu Formation and constitute its lateral equivalents in most places. In the Paleocene, the marine shales of the Imo and Nsukka Formations were deposited, overlain by the tidal Nanka Sandstone of Eocene age. Downdip, towards the Niger Delta, the Akata Shale and the Agbada Formation constitute the Paleogene equivalents of the Anambra Basin . The Enugu and the Nkporo Shales represent the brackish marsh and fossiliferous pro-delta facies of the Late Campanian-Early Maastrichtian depositional cycle (Reijers and Nwajide,1998). Deposition of the sediments of the Nkporo/EnuguFormations reflects a funnel-shaped shallow marine setting that graded into channeled low-energy marshes. The coal-bearing Mamu Formation and the Ajali Sandstone accumulated during this epoch of overall regression of the Nkporo cycle.The Mamu Formation occurs as a narrow strip trending north–south from the Calabar Flank, swinging west around the Ankpa plateau and terminating at Idah near the River Niger (Obaje, 2009). The Ajali Sandstone marks the height of the regression at a time when the coastline was still concave. The converging littoral characteristic for the Ajali Sandstone. The Nsukka Formation and the Imo Shale mark the onset of another transgression in the Anambra Basin during the Paleocene. The shales contain significant amount of organic matter and may be a potential source for the hydrocarbons in the northern part of the Niger Delta (Reijers and Nwajide, 1998).

3. Methodology

The lithologic variation in the study area necessitated collection of representative samples from all the traversed rocks for the purpose of determining the approximate densities of the surface rocks. Thirty-one rock samples were collected and subjected to density determination in the laboratory. A spring balance was used for the measurement (to an accuracy of 0.01gm).

The method of measurement was a modification of Ajakaiye's (1976) method.

Weight of dry sample in air = w_d
Weight of dry sample in water = w_w
After 24-hours saturation of samples,
Weight of the sample in air = w_t
Weight of sample in water = w_s
Specific gravity or dry bulk density $\frac{wd}{w_d - w_w}$
Saturated density = $\frac{wt}{w_t - w_s}$

4. Results And Discussions

Table 1 shows the dry and saturated densities of the various rock samples presented according to their suite; metamorphic; igneous and sedimentary. The dry bulk density of the metamorphic rocks ranges from 2.33gm/cm^3 to 2.77 gm/cm^3. The samples were dominated by schist of varying metamorphic minerals. There exists a slight difference between the dry bulk density and the saturated density of the metamorphic rocks, up to the magnitude of 0.11gm/cm^3. In the case of igneous rocks, the density ranges from 2.34 to 2.73gm cm^{-3}. There was no significant difference between their dry bulk densities and saturated densities. The sedimentary outcrops, sandstone covered the ranges of hills, with some ferruginized and lateritized caps. The dry densities of the sandstone samples ranges from 1.85gm/cm to 2.45gm/cm^3. A slight difference exists between the dry bulk density and the saturated density. The latter was almost consistently greater than the dry bulk density of the sandstone samples.

The measured density values were used to deduce the surface (to near-surface) rock density which used in figure 1. An average rock density worked out for each profile based on the density of the rocks that outcrop along the profile (figure 2) is stated below:

1) The Emi-Adama- Gboloko Profile: A mean density of 2.60gm/cm^3 was obtained, based on the densities of the schists and gabbro rocks traversed.
2) The Shintaku-Gboloko Profile: An average density of 2.50 gm/cm^3 was obtained. This profile traversed Schist, gneisses, migmatites, intrusive granites and pegmatites.

3) The Gboloko-Odugbo Profile: An average density of 2.40gm/cm^3 was obtained. This was an approximation based on the densities of samples of mica-schist and sandstone traversed.

However, the near-surface or crustal densities in the area are likely to differ from those of surface rocks because of possible variation in subsurface geology.

Table 1: Densities of the Metamorphic Rocks

Rock type	No of samples	Dry density range (gm/cm^3)	Mean dry density g/cm^3	Saturated density range g/cm^3	Mean wet density g/cm^3
Schist	14	2.33 – 2.77	2.55	2.43 – 2.89	2.66
Gneiss	2	2.20 – 2.48	2.34	2.40 – 2.56	2.48

Table 2: Densities of the Igneous Rocks

Rock type	No of sample	Dry/saturated density range (gm/cm)	Mean dry/ weight density
Gabbro	4	2.54 – 2.73	2.64
Granite	3	2.39 – 2.58	2.49
Pegmatite	1	2.34	

Table 3: Densities of the Sedimentary Rocks

Rock type	No of sample	Dry density range (gm/cm^3)	Mean dry density g/cm^3	Saturated density range g/cm^3	Mean wet density g/cm^3
Sandstone	7	1.85 – 2.55	2.10	1.91- 2.45	2.18

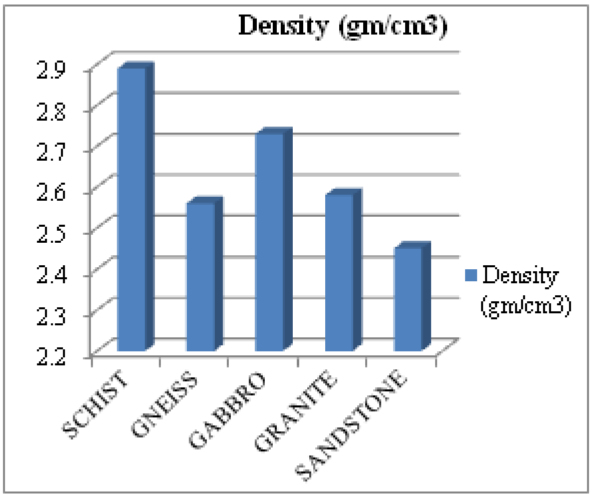


Figure 1: Increasing trend of rock density values, from sedimentary to igneous to metamorphic rocks.

5. Magnetic Susceptibility Measurement

To assist in the interpretation of the magnetic data, magnetic susceptibility measurements were carried out on thirty one rock samples from the study area. The measurements estimated the degree to which the rocks could be magnetised. It is given as the ratio of the intensity of magnetization I of the rock to the magnetic field (H) responsible for the magnetization.

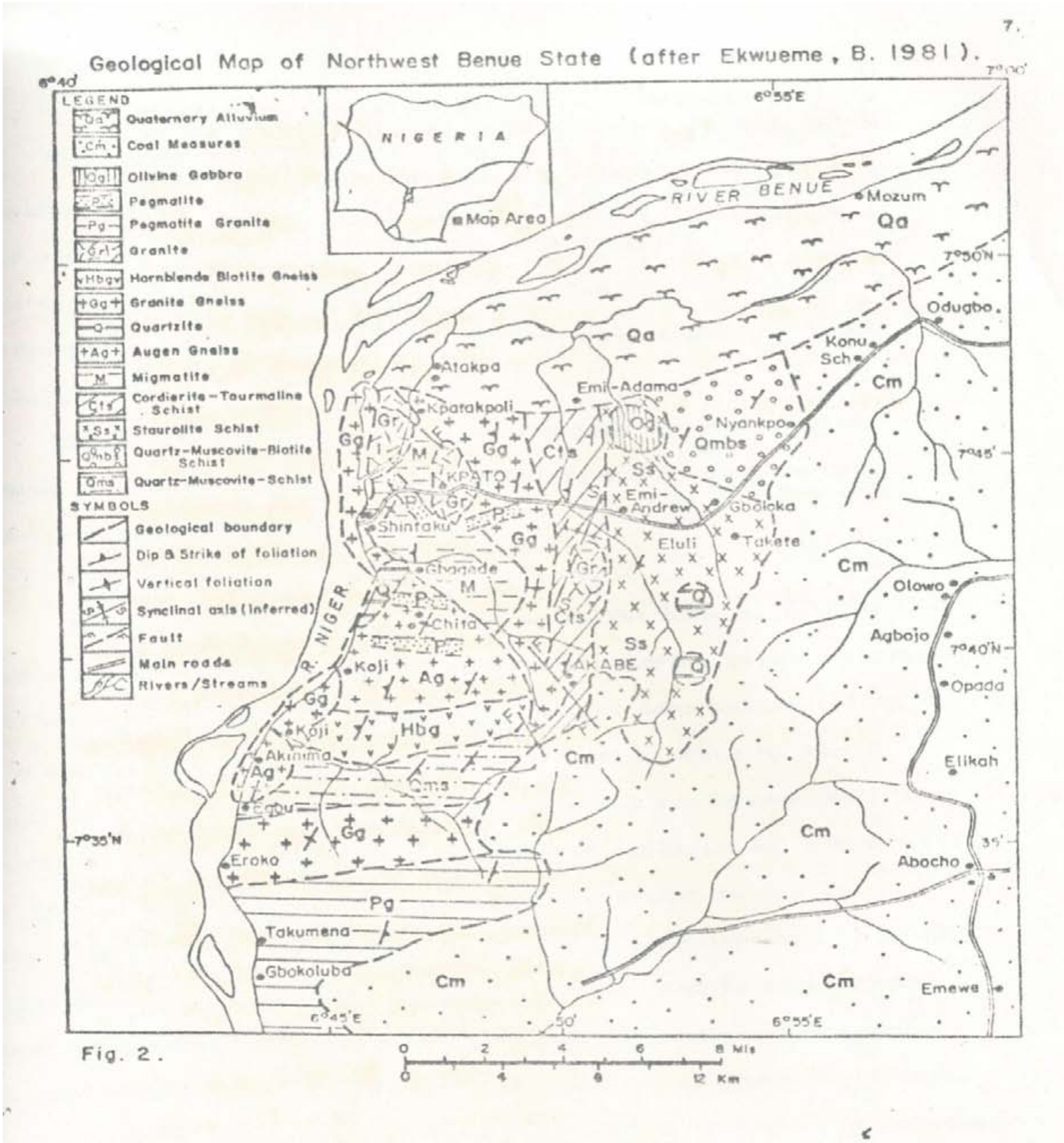
The measurement was made with a Scintrex Core Testing Instrument.

Positive deflection is obtained from the instrument by the use of the polarity knob (+, -). The instrument reading is indicated on the dial, which displays readings according to the range in use. The magnetic susceptibility was then obtained from the instrument reading, by tracing it graphically in the conversion chart provided in the instrument manual.

The magnitude of the susceptibility depends on the presence of such magnetic minerals (Petters, 1949). as magnetite and the mafic igneous the rocks such as gabbro shown on figure 3. The magnetic susceptibility of the various rocks is shown in table 4. The magnitude of this quantity ranges from 0.0001 to 0.00015 emu for the metamorphic rocks. From available data, it is probable that the Cordierite-Tourmaline Schist has a higher magnetic susceptibility of 0.00015 emu, than other metamorphic rocks in the area.

Table 4: Magnetic Susceptibility of Various Rock Types in the Basement Complex Area

Rock Type	No of Samples	Instrument Reading	Magnetic Susceptibility Range (emu)
Staurolite-Schist	12	0.5 – 1.1	0.0001 – 0.00011
Quartz-Muscovite Biotite Schist	5		
Cordierite-Tourmaline Schist	2	1.5	0.00015
Gneiss	2	0.6	
Gabbro	5	8.6 – 9.5	0.00086 - 0.00095
Granite	3	0.6 – 1.5	0.00015
Pegmatite	1	2.25	0.00023
Sandstone	6	0.5 – 1.2	0.00012



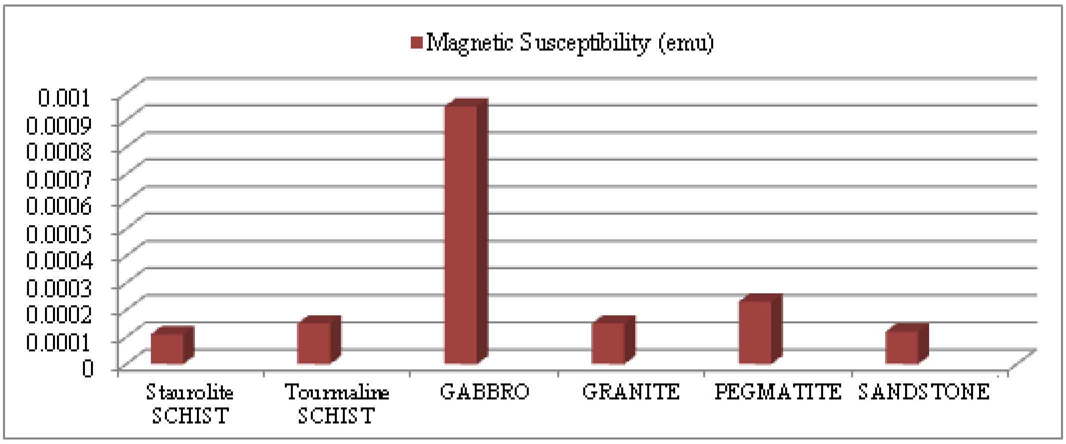


Figure 3: Showing Trending of Magnetic Susceptibility values from Sedimentary rock type (Sandstone) to the mafic Igneous rock (gabbro), to the metamorphic rock types (schists)

6. Conclusion

Evidently, density and magnetic susceptibility measurements followed a consistent pattern that revealed the environment of the parent rocks, the mafic and alkaline igneous rocks, the metamorphic and sedimentary rocks. The mafic igneous rocks such as the gabbros have greater magnetic susceptibility (of magnitude 0.00089 to 0.00095) emu epitomizing high level of iron-content. The alkaline igneous rocks such as granites have congruous magnitudes both in density and magnetic susceptibility with the sedimentary rocks such as sandstone.

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