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

Madu Anthony Joseph Chinonyeze¹, Anoke Aniebonam Ignatius², Onuoha Mosto K.³

¹, ²Department of Geology, College of Physical and Applied Sciences, Michael Okpara University of Agriculture Umudike, Abia State, Nigeria
³Holder, PTDF Professorial Chair, Department of Geology, Faculty of Physical Sciences, University of Nigeria Nsukka UNN, Enugu State, Nigeria

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/cm³ to 2.35gm/cm³ 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/cm³. 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/cm³ to 2.77gm/cm³ with a slight difference of 0.41gm/cm³ and dominated by schists while the igneous rocks ranged from 2.34gm/cm³ to 2.73gm/cm³ 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 (Adelye, 1976). The dry bulk and saturated densities of the various samples were determined. The sedimentary rocks which were dominantly sandstones ranged from 1.85gm/cm³ to 2.35gm/cm³ 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/cm³. 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/cm³ to 2.77gm/cm³ with a slight difference of 0.41gm/cm³ and dominated by schists (Ojo and Ajakaiye, 1976). while the igneous rocks ranged from 2.34gm/cm³ to 2.73gm/cm³ 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 pre-dating 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
pyroclastics of Aptian
the depocenters comprise Pindiga, Gombe, Nafada, Ashaka
Lafia, Obi, Jangwa to Wukari. In the Upper Benue Trough,
Trough comprises the areas from Makurdi through Yandev,
around Enugu, Awka and Okigwe. The Middle Benue
and Abakaliki, while those of the Anambra Basin centre
Benue Trough comprise mainly the areas around Nkalagu
towns/settlements) that constitute the depocentres of the
demarcate the individual portions, though major localities
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
together with the previous ( 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 siltstones)
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 Masu 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.

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 = \( \frac{w_f}{w_d - w_w} \)
Saturated density = \( \frac{w_t}{w_d - w_w} \)

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/cm³
and 2.77 gm/cm³. 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/cm³. 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/cm³. 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/cm³ 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/cm² was obtained. This profile traversed Schist,
gneisses, migmatites, intrusive granites and pegmatites.
3) The Gboloko-Odagbo Profile: An average density of 2.40 gm/cm³ 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

<table>
<thead>
<tr>
<th>Rock type</th>
<th>No of samples</th>
<th>Dry density range (gm/cm³)</th>
<th>Mean dry density g/cm³</th>
<th>Saturated density range g/cm³</th>
<th>Mean wet density g/cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schist</td>
<td>14</td>
<td>2.33 – 2.77</td>
<td>2.55</td>
<td>2.43 – 2.89</td>
<td>2.66</td>
</tr>
<tr>
<td>Gneiss</td>
<td>2</td>
<td>2.20 – 2.48</td>
<td>2.34</td>
<td>2.40 – 2.56</td>
<td>2.48</td>
</tr>
</tbody>
</table>

### Table 2: Densities of the Igneous Rocks

<table>
<thead>
<tr>
<th>Rock type</th>
<th>No of sample</th>
<th>Dry/saturated density range (gm/cm³)</th>
<th>Mean dry/ weight density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gabbro</td>
<td>4</td>
<td>2.54 – 2.73</td>
<td>2.64</td>
</tr>
<tr>
<td>Granite</td>
<td>3</td>
<td>2.39 – 2.58</td>
<td>2.49</td>
</tr>
<tr>
<td>Pegmatite</td>
<td>1</td>
<td>2.34</td>
<td></td>
</tr>
</tbody>
</table>

### Table 3: Densities of the Sedimentary Rocks

<table>
<thead>
<tr>
<th>Rock type</th>
<th>No of sample</th>
<th>Dry density range (gm/cm³)</th>
<th>Mean dry density g/cm³</th>
<th>Saturated density range g/cm³</th>
<th>Mean wet density g/cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone</td>
<td>7</td>
<td>1.85 – 2.55</td>
<td>2.10</td>
<td>1.91 – 2.45</td>
<td>2.18</td>
</tr>
</tbody>
</table>

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 magnetized. 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 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

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

References