Economic Prospects of Nepheline Syenites Occurring Around Awo, Southwestern, Nigeria

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Abstract
Nepheline syenites are purplish, iridescent intrusive igneous rocks of granitic composition that can be cut, trimmed and polished as dimension stones for various construction and decorative purposes. The rocks can also be a raw material for the manufacture of glass and ceramics. Other rock types that occur in association with the syenites include migmatite gneiss, biotite gneiss, quartzite, schists, granite and pegmatite. Geological field mapping was conducted to collect rock samples and to ascertain the areal extent of the rocks. Other investigation carried out include cutting the thin sections of the five representative rock samples, cross examination of the thin sections under petrological microscope to comprehend and determine the petrographic characteristics of the various minerals present in the rock. This investigation is targeted at studying some physical and petrographic properties of the rock with a view to determining its functional and industrial application in dimension stone, glass and ceramic manufacturing among others. The petrographic examination carried out on the rock samples collected from the study area showed that nepheline syenite is made up of various minerals like Alkali feldspar (38.32%) plagioclase (9.11%), Nepheline (3.3%), Biotite (7.9%), Hornblende (6.71%), Quartz (3.31%) and accessory minerals (1.36%). Petrography also revealed the characteristic features of each constituent mineral like the cross hatched twinning in alkaline feldspar, polysynthetic twinning in plagioclase, pleochroic biotite and hornblende. The rock is very rich in feldspar and poor in quartz making it a suitable raw material in the manufacture of glass and ceramics. The colour and iridescent appearance makes it useful in architecture, ornamentation, facade, monument and dimension stones. In order to achieve the Millenium Development Goals (MDGs) by creating wealth and alleviating poverty through structured and organised mining. The expansive rock deposits which are explorable and exploitable could be a source of generating huge revenue by setting up quarries, mining and mineral processing industries for the production of dimension stones, glass and ceramics manufacturing and various construction purposes.

Keywords: nepheline syenites, dimension stones, feldspar, iridescent, pleochroic

INTRODUCTION
The pre-cambrian basement complex of Awo is made up of heterogeneous composition of different rock types like granites, syenites, pegmatites, schists, gneisses and quartzites (fig 1). These rock varieties play a very crucial role by serving as hosts for many economic minerals that are useful to mankind. The rock bodies themselves are used for various building, construction, monument and decorative purposes. This research is devoted to studying the physical and mineralogical properties of syenites in Awo with a view to highlighting the geological and techno-economic feasibilities of the syenites in building and road construction, glass and ceramic manufacturing, dimension stones, monuments, facade, decorative and other industrial purposes.

Texture of the syenites are coarse to medium grained, veins which are mostly quartzitic and quartzofeldspathic in composition appear on the rock surface as wavy, semicircular thin laminations (fig 2). The rock forms a massive, bouldery, ovoid small hillock without any preferred orientation of the interlocking mineral grains. Hand specimen observation of the rock samples from different locations around Awo revealed varying proportions of the constituent minerals like alkali feldspar (microcline), nepheline, biotite, amphibole (hornblende), clinopyroxene (augite). Accessory minerals include sphene, quartz, apatite and opaque minerals.

Syenites of the area bear compositional similarities with those described by Negm et al (2000) in Eastern desert of Egypt. The mineralogy of syenite from the Egyptian localities consists of minerals like orthoclase, nepheline, biotite, hornblende and augite. Guillet (1994) also described syenites with appreciable amount of nepheline as feldspathoidal rocks that are indispensable raw materials in glass, ceramics and fillers production. Nepheline syenites are generally enriched in alkalis (Na₂O and K₂O) and alumina (Al₂O₃) contents. Dimension stones were described by Egesi and Tse (2011) as natural stones or rocks that were selected, trimmed, cut, drilled and ground to specific sizes and shapes. Colour, texture,
pattern, location of deposits and surface finish of the stone are of economic or commercial requirements. Nepheline syenites exhibit surfacial weathering in some rock exposures as durability is an essential factor influencing the selection of a rock for dimension stone. Nepheline syenites of Awo are able to maintain their mechanical strength, resistance to weathering and appearance.

Nepheline syenite crystallises in the hexagonal system with a distinct imperfect cleavage and subconchoidal fracture. The rocks’ hardness range from 5.5-6.0 while the specific gravity is between 2.5 and 2.7.

In terms of field occurrence, Minnes, et al (1983) and Guillet (1994) described nepheline syenites as a light-coloured, iridescent igneous rock which is similar to granite in its medium to coarse grained appearance, these alkali-rich rocks are deficient in silica, small amounts of biotite, hornblende, magnetite, pyroxene, muscovite, apatite, ilmenite and zeolite act as impurities which confer purplish, pinkish, greyish colouration on the rock (fig 2). Hewitt (1961), described essential minerals in nepheline rocks to be composed of nepheline, sodic plagioclase (albite or oligoclase) and microcline while small amounts of biotite, hornblende, magnetite, pyroxene, muscovite, sodalite, garnet, zircon, apatite, ilmenite, calcite, pyrite and zeolite occur as impurities or colouring minerals.

**METHODOLOGY**

Detailed geological mapping was conducted in order to study field relationship of the rock bodies available in the area. Rock samples were collected during the mapping exercise from major outcrops and abandoned quarry. A total of five representative samples were selected for physical observation, textural characteristics and petrographic examination. Unpolished (thin) section of the rock samples were prepared by using a rock cutting machine, one side of the rock was ground and polished until a plane surface was obtained; the surface was mounted on a glass slide with an epoxy. The rock samples mounted on glass slides were heated to a temperature above 100°C. The samples were further ground to a thickness of about 0.03mm using varying sizes of silicon carbide powder. These thin sections were then covered with cover slip using Canada balsam.

**PETROGRAPHIC EXAMINATION**

Microscopic examination of nepheline syenite samples consists of perthitic orthoclase, albite (50-70%), nepheline (15-25%) and hornblende (4-6%). Other accessory minerals include small amounts of augite, biotite and hornblende with traces of free silica (Negm et al, 2000). Petrographic studies are necessary to identify the rock mineralogy, grain size, texture, fabric and weathering states. Nepheline syenites around Awo show the presence of alkali feldspar (microcline), plagioclase feldspar, nepheline with small amounts of hornblende biotite and quartz. The microclines are also perthitic in some specimen (fig. 3) perthite and nepheline are generally unaltered,
there are no visible twinnings and the cleavage is poor. Estimated modal compositions of the syenite obtained from this study are shown in table 1 below.

Table 1: Estimated modal composition of Awo syenite as obtained from this study

<table>
<thead>
<tr>
<th>Minerals</th>
<th>Location 1</th>
<th>Location 2</th>
<th>Location 3</th>
<th>Location 4</th>
<th>Location 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcline</td>
<td>37.80</td>
<td>36.20</td>
<td>42.3</td>
<td>45.30</td>
<td>30.00</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>9.20</td>
<td>9.00</td>
<td>8.50</td>
<td>8.10</td>
<td>8.60</td>
</tr>
<tr>
<td>Nepheline</td>
<td>33.00</td>
<td>33.80</td>
<td>31.20</td>
<td>30.00</td>
<td>30.00</td>
</tr>
<tr>
<td>Biotite</td>
<td>11.80</td>
<td>7.60</td>
<td>5.24</td>
<td>14.30</td>
<td>10.75</td>
</tr>
<tr>
<td>Hornblende</td>
<td>11.80</td>
<td>7.60</td>
<td>5.24</td>
<td>0.36</td>
<td>8.54</td>
</tr>
<tr>
<td>Quartz</td>
<td>2.30</td>
<td>6.20</td>
<td>5.50</td>
<td>1.20</td>
<td>1.34</td>
</tr>
<tr>
<td>Other minerals</td>
<td>1.30</td>
<td>3.00</td>
<td>0.40</td>
<td>0.50</td>
<td>1.62</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>99.60</td>
<td>99.2</td>
<td>99.99</td>
<td>99.76</td>
<td>99.96</td>
</tr>
</tbody>
</table>

Fig 3: Showing the average distribution of minerals in syenite of the study area

**PHYSICAL PROPERTIES**

Physical properties such as specific gravity, strength, porosity, abrasiveness and aesthetic luster were determined by Elueze (1995), he noted that the average specific gravity of syenites from the basement complex of south western Nigeria is 2.79. In addition to the specific gravity, syenites around Awo have a high standard strength of about 9.34, low water absorption capacity (0.31%) and low oil absorption capacity (0.09%). Apart from the properties mentioned above, nepheline syenite has a very high melting point of about 1100°C, it also possesses a low optical dispersion and refractive index. Due to its low silica content, nepheline syenite poses a low environmental and health risk than feldspar. Deere and Miller (1966) and Bieniawski (1975) pointed out that rocks whose colour index are melanocratic (dark coloured) are commonly of very high strength, this factor determines the functional application of nepheline syenite in glass and ceramics manufacturing, flux and dimension stone production. However, structural dislocations, weathering effects, occurrence of veins, xenoliths, boudins, are obvious limitations to the functional use of these rock assemblages.

**RESULTS AND DISCUSSION**

Studies of the five rock samples selected for microscopic examination showed an average simple mineralogy which is in most cases dominated by feldspar (microcline is made up of 38.32% and plagioclase consists of 9.11%), nepheline 33%, biotite averages 7.9%, hornblende averages 6.71% while quartz averages 3.31%. Other accessory minerals like magnetite, ilmenite, apatite, zircon, garnet, calcite, pyrite and zeolite altogether average 1.36% in composition (table 2).

Each constituent mineral exhibited its characteristic features under the microscope. Microcline has tartan or cross-hatched twinning, plagioclase (albite) showed the polysynthetic twinning, microperthite is also noticeable in some unpolished sections. Nepheline has no twinning and cleavage but possesses a subconchoidal fracture which makes it resemble quartz in thin section. Biotite is brownish in colour, the mineral appear flaky with goose pimple or mottled appearance, biotite is pleochroic, its basal cleavage is perfect. Hornblende maintains a brownish to greenish colouration under the microscope, its cleavage is perfect in two directions (56 and 124 degrees), and simple lamellar twinning is common in hornblende (fig 4). Petrographic studies of the samples generally indicated that nepheline syenites possess an interlocking grain boundary which is an important feature in economic evaluation of a rock for dimension stone production, industrial application or decorative purposes.

In summary, mineralogical composition of nepheline syenites of Awo bear close similarities with those occurring in other parts of south western Nigeria (table 2).

![Fig 4: Photomicrograph of syenite showing microcline, M, plagioclase,P, biotite, B, hornblende, H, and quartz, Q, Nepheline, N](image_url)

Magnification: × 40 xpl
Table 2: Comparative modal composition of syenite in Southwestern Nigeria

<table>
<thead>
<tr>
<th>Minerals</th>
<th>Igarra syenite</th>
<th>Oyo syenite</th>
<th>Shaki syenite</th>
<th>Offa syenite</th>
<th>Awo syenite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcline</td>
<td>58.19</td>
<td>40.25</td>
<td>43.63</td>
<td>52.18</td>
<td>38.32</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>5.60</td>
<td>45.45</td>
<td>45.23</td>
<td>32.22</td>
<td>9.11</td>
</tr>
<tr>
<td>Nepheline</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>33.00</td>
</tr>
<tr>
<td>Biotite</td>
<td>6.35</td>
<td>5.91</td>
<td>4.12</td>
<td>3.85</td>
<td>7.90</td>
</tr>
<tr>
<td>Hornblende</td>
<td>24.46</td>
<td>6.33</td>
<td>5.11</td>
<td>6.15</td>
<td>6.71</td>
</tr>
<tr>
<td>Quartz</td>
<td>5.79</td>
<td>2.21</td>
<td>1.23</td>
<td>5.45</td>
<td>4.31</td>
</tr>
<tr>
<td>Total %</td>
<td>100.89</td>
<td>100.15</td>
<td>99.32</td>
<td>99.85</td>
<td>99.35</td>
</tr>
</tbody>
</table>


**ECONOMIC GEOLOGY AND EVALUATION OF NEPHELINE SYENITE.**

Nepheline syenite owes its commercial and economic evaluation to mineralogical composition and physical parameters like colour, texture, grain size, specific gravity, refractive index and hardness. Location of the deposit and purity are also important. (Negm et al, 2000). Purity is determined by the proportion of accessory minerals like biotite, hornblende, magnetite, ilmenite, apatite, garnet, zircon and other ferromagnesian minerals which impart different colouration on nepheline syenite. The rock is an indispensable raw material in the production of dimension stones monuments, architectural designs, facade, building and road construction due to its high mechanical strength and resistance to weathering. Despite the fact that the rock has a high melting point of about 1100°C, its low fusion point promotes faster melting, higher productivity and fuel savings in glass and ceramics industry (Guillet, 1994). Nepheline syenite also has a high fluxing capacity which allows it to act as a good vitrifying or glazing agents. The rock also has functional application as an inert fillers in plastics and paint production when finely ground. Mining of rocks generally (rock like nepheline syenite) leads to serious environmental pollution and degradation hence there is need for adequate monitoring and control. Blasting exercise should be regulated and checked, likewise drilling techniques and machineries should be specialised in order to minimise noise and other environmental disturbances generated by blasting. Factors like the availability, cost of transportation access, labour, machinery and market are relevant to the viability of the enterprises. Factories should also be located near the working site for the processing or finishing stages and to reduce haulage expenses (Elueze and Okunlola, 2003).

**CONCLUSION**

This study has revealed that the field, petrographical and mineralogical evidences provide a useful indication about the economic geology and evaluation of nepheline syenite around Awo. The rock forms an explorable and exploitable deposit for the glass and ceramics manufacturing, dimension stone production, paint and plastics manufacturing, road and building construction among others. In line with the Federal government effort to diversify the economy and expand its revenue generation base, solid mineral sector should be fully developed to serve as credible alternative to petroleum resources. Furthermore, for the millennium development goals to be achieved, government of developing nations like Nigeria should empower its teeming population by creating wealth and job opportunities in the hitherto unknown solid mineral sector of the economy.

**REFERENCES**


