

Major Element Geochemical Characteristics of the Granitic Basement Complex Rocks of WADILI Area, North-Eastern Nigeria

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ABSTRACT

Wadili village (North-Eastern Nigeria) and surrounding areas in Mubi Local Government of Adamawa State was mapped to determine the major element compositions of the rocks. The area is part of the Upper Benue Trough of Nigeria. The rocks mapped were described and field studies indicate that they belong to the Precambrian-Cambrian crystalline basement complex rocks of Nigeria. The rocks include porphyritic granites, coarse-grained granites, medium-grained granites and fine-grained granites which serve as the major rock types, with pegmatites, dolerites and migmatite-gneisses as the minor units. The representative rock samples collected from the field were prepared by crushing, pulverization and digestion. The samples were analysed geochemically by using X-Ray Fluorescence (XRF) and Atomic Absorption Spectrometry (AAS) to determine their concentration for major elements while Loss on Ignition (LOI) was used to determine the final weight loss after ignition. Chemical variation plots of the Wadili granites indicate that the rocks are highly siliceous (acidic), metaluminous and calc-alkaline in nature. In addition, most of the rocks plot within the igneous field, thereby comparing favourably well with those obtained from other basement complex areas of Nigeria.

Keywords: Major Elements; Granites; Geochemical Analysis; Acidic; Metaluminous; Calc- Alkaline; Wadili Area (North-Eastern Nigeria).

1. INTRODUCTION

Wadili area is shown to be dominantly underlaid by basement rocks amongst which are granitic members. The rocks are mainly granite outcrops practically forming the Wadili hills. They vary in texture from fine to medium, to coarse and porphyritic variants with gradation between them. Other basement rocks such as migmatite-gneisses, dolerites and pegmatites were also mapped in the area.

The aim of the project is to provide major element geochemical data of the granitic rock types being encountered in the study area with the use of X-Ray Fluorescence (XRF) and Atomic Absorption Spectrometry (AAS) to determine their concentration for major elements and Loss on Ignition (LOI) to determine the final weight loss after ignition. This geochemical data will provide the chemical composition of

these granites and further help to broaden the knowledge of the geochemistry of the basement rocks of north-eastern Nigeria by way of inferring the origin and mode of occurrence of these rocks.

2. REVIEW OF ANALYTICAL PROCEDURE

Atomic Absorption Spectrometry (AAS) is a spectro-analytical procedure for the quantitative determination of chemical elements using the absorption of optical radiation (light) by free atoms in the gaseous state. In analytical chemistry, the technique is used for determining the concentration of a particular element (the analyte) in a sample to be analysed. AAS can be used to determine over seventy different elements in solution or directly in solid samples used in pharmacology, biophysics and toxicology research. The

technique makes use of absorption spectrometry to assess the concentration of an analyte in a sample. It requires standards with known analyte content to establish the relation between the measured absorbance and the analyte concentration. In short, the electrons of the atoms in the atomizer can be promoted to higher orbital (excited state) for a short period of time (nanoseconds) by absorbing a defined quantity of energy (radiation of a given wavelength). This amount of energy is specific to a particular electron transition in a particular element. In general, each wavelength corresponds to one particular element, and the width of an absorption line is only of the order of a few picometers (pm), which gives the technique its elemental selectivity. In order to analyze a sample for its atomic constituents, it has to be atomized. The atomizers mostly used nowadays are flames and electrothermal (graphite tube) atomizers. The processes in a flame include desolvation (drying), vaporization, atomization and ionization while for electrothermal AAS, the stages involve drying, pyrolysis, atomization and cleaning.

X-ray Fluorescence (XRF) is the emission of characteristic “secondary” (or fluorescent) X-rays from a material that has been excited by bombarding with high energy X-rays or gamma rays. The phenomenon is widely used for elemental analysis and chemical analysis, particularly in the investigation of metals, glass, ceramics and building materials, and for research in geochemistry forensic science and archeology. When materials are exposed to short-wavelength X-rays or to gamma rays, ionization of their component atoms may take place. Ionization consists of the ejection of one or more electrons from the atom, and may occur if the atom is exposed to radiation with energy greater than its ionization potential. X-rays and gamma rays can be energetic enough to expel tightly held electrons from the inner orbitals of the atom. The removal of an electron in this way makes the electronic structure of the atom unstable, and electrons in higher orbital fall into the lower energy orbital to fill the hole left behind. In falling, the energy is released in the form of a photon, the energy of which is equal to the energy difference of the two orbital involved. Thus, the material emits radiation, which has energy characteristic of that atoms present. The term fluorescence is applied to phenomena in which the absorption of radiation of a specific energy results in the re-emission of radiation of a different energy (generally lower).

3. MATERIALS AND METHODS

Six granite rock samples were analyzed for their major element composition, using Atomic Absorption Spectrometry (AAS) and X-ray Fluorescence (XRF) and Loss on Ignition (LOI) to determine the initial and final weight loss after ignition. The six granite samples were collected from the field during the mapping exercise. The rock samples were collected from the field based on strict adherence to field procedures. Samples collected from the field were first identified based on hand specimen.

3.1 Preparation of Geochemical Samples

(a) **Crushing/Pulverization:** The rock samples were crushed with the hammer to reduce the sample size while maintaining representativeness of sub-samples. The rock samples were further pulverized into powdered form by a disc miller machine made of iron and steel.

(b) **Digestion:** Concentrated mineral acids (HNO_3 and HCl) were used to digest the powdered samples in a crucible by heating it in a hot plate. The acid destroys the silicate lattice of the main reacting minerals. A reddish or yellowish solution was obtained after dissolution of the powdered samples. After digesting the samples, they were taken for geochemical analysis.

3.2 Geochemical Analysis (AAS, XRF, LOI)

(a) **X-Ray Fluorescence (XRF):** The rock samples were radiated with electrons or x-rays of sufficient energy. 2X-rays were emitted at different wavelengths and intensities specific for the elemental composition of the different samples. Measurement of the intensity of 2^0 characteristics radiation form basis for XRF. Fluorescent X-rays of different wavelengths are characteristic of activated elements emitted.

(b) **Atomic Absorption Spectrometry (AAS):** The solution containing certain element was introduced (sprayed) into the flame of an adequate temperature. Elements are then transformed into free atoms due to excitation by the flame energy. The uncharged atoms in vapour state absorb photon of light energy appropriate for excitation of outer electron. The intensity of light absorbed at a specific wavelength from the beam by the flame containing the atoms was directly

proportional to the atoms concentration in the flame or light path and hence element concentration in the solution. The results were also displayed as concentration readout.

(c) Loss on Ignition: The representative samples were weighted and ignited at 1100°C for 1 hour in a furnace. The differences in the initial and final weight were then calculated in percentage weight (% wt).

4. RESULTS AND DISCUSSION

Chemical analyses of igneous rocks from a particular igneous province almost invariably show a considerable variation in the concentrations of individual elements. These elements are usually plotted on variation diagrams. Variation diagrams expresses the idea that igneous rocks which are closely associated in time and space often substantial variation. Sometimes, such variation is confined within certain limits and is used to express the gross differences which exist between ranges of compositional types present in one province as opposed to another. One of the preliminary tasks in any research study is to devise a means of describing and displaying variation so that the numerous data for the individual rocks become simplified condensed and rationally classified. Six granite rock samples were analyzed for their major element composition, using Atomic Absorption Spectrometry (AAS) and X-ray Fluorescence (XRF) and the results presented as table 1.

The chemical data above show minor variation as far as individual oxides are concerned with SiO₂ ranging from 72.000% - 72.841%; Al₂O₃ ranging from 6.602% - 6.903%; K₂O ranging from 3.504% - 4.007%; Na₂O ranging from 2.0% - 5.0%; CaO ranging from 0.783% - 0.822%; Fe₂O₃ ranging from 0.675% - 0.937%; MnO ranging from 0.19% - 0.66%; MnO ranging from 0.01% - 0.10% and LOI ranging from 0.1% - 0.59% respectively.

4.1 Interpretation

When plotted on Harker's variation diagrams (SiO₂ vs. major oxides) in Fig.2, all the oxides show increase with increasing silica except for Al₂O₃, K₂O and Na₂O. This indicates the removal of plagioclase minerals in the course of crystallization although the increase in the SiO₂ may indicate more fractionation. The behavior of these oxides compare very well

with other analysis of alkali rocks from the Barberton region, South-Africa as reported by Condle et al, 1976.

A plot of CaO, (Na₂O+K₂O) against SiO₂ (Fig.3) shows that CaO decrease slightly with the increase in SiO₂ while (Na₂O+K₂O) increases with increase in SiO₂. Curves for more alkaline rocks intersect at lower silica content (Fig.2) and the silica content can be used to further sub-divide the rocks into series.

Igneous rocks are classified into four (4) based on their silica (SiO₂) content The alkalis Na₂O and K₂O have an average value of 3.067% and 3.835% respectively while CaO has an average value of 0.807%. In total Na₂O, K₂O and CaO is 7.709% which is greater than the average alumina content of the rocks (6.759%). This provides for designation of the Wadili granites as **metaluminous**. Al₂O₃>Na₂O+K₂O <Na₂O+K₂O+CaO (table 3).

Generally, the Iron and Magnesium oxides (Fe₂O₃ and MgO) are very low in all the samples analyzed. The average value of Fe₂O₃ is 0.834%, MgO is 0.378% which is a clear indication that the rock samples are acidic.

Manganese Oxide (MnO) has the lowest concentration in all the rock samples with an average concentration of 0.07%. This is quite usual for a typical granite particularly the one under study with the highest value 0.10% for samples SI and L2S1 respectively.

The percentages of SiO₂, Al₂O₃ and ferromagnesian minerals (MgO, Fe₂O₃) indicate the source of the magma. However, Wadili granites seem to originate from the lithosphere rather from the upper mantle because they compose chiefly of Silica (SiO₂) and Alumina (Al₂O₃) or as a result of fractional crystallization of early formed minerals which tend to separate from the silicate melt and settle at the bottom by gravity settling thereby enhancing the silica and alumina content of the melt.

The plot of alkalinity ratio (Na₂O+K₂O) against Silica (SiO₂) in Fig.6 further reveal that most of the rocks are calc-alkaline as compared to the Pulka granites in Gwoza as reported by Baba (2006).

The plot of Na₂O₃/Al₂O₃ versus K₂O/Al₂O₃ indicate that most of the granites around Wadili area are of igneous origin (Fig.7), with only few plotting within sedimentary and metasedimentary field. This compare very well with those

obtained from other parts of the Nigerian basement complex (Onyeagocha, 1986).

The CaO-Na₂O-K₂O triangular plot for the Wadili granites (Fig. 8) confirms that normative compositions place the granites within granodiorite, quartz-monzonite and granitic fields. All the samples plotted in the granitic field indicate some degree of fractional crystallization.

5. SUMMARY

Granite samples from Wadili area were prepared in a geochemical laboratory by crushing, pulverization and digestion. The prepared samples were analyzed geochemically by the use of X-ray fluorescence (XRF) and Atomic Absorption Spectrometry (AAS) to determine their concentration for major elements while Loss on Ignition (LOI) to determine the final weight loss after ignition. Chemical characteristics of these granites indicate that SiO₂ is the most abundant oxide followed by Al₂O₃, K₂O, Na₂O, CaO, Fe₂O₃, MgO and MnO in decreasing order. The result show great similarities between the analyzed samples. As it is known to be common with granites, silica content (SiO₂) is greater than 70% for all the samples, which is *acidic*. Based on alumina content, the rocks of are *metaluminous* (Al₂O₃<Na₂O+K₂O+CaO), while most of the plot within the igneous field indicate the magmatic evolution of the rocks. *Calc-alkaline* nature is also indicative of the Wadili granite. Major element concentrations and their ratios as well as chemical variation diagrams plotted in this work has established a petrogenetic history between granitic outcrops in Wadili and other areas especially the Pulka granites in Gwoza area, north-eastern Nigeria.

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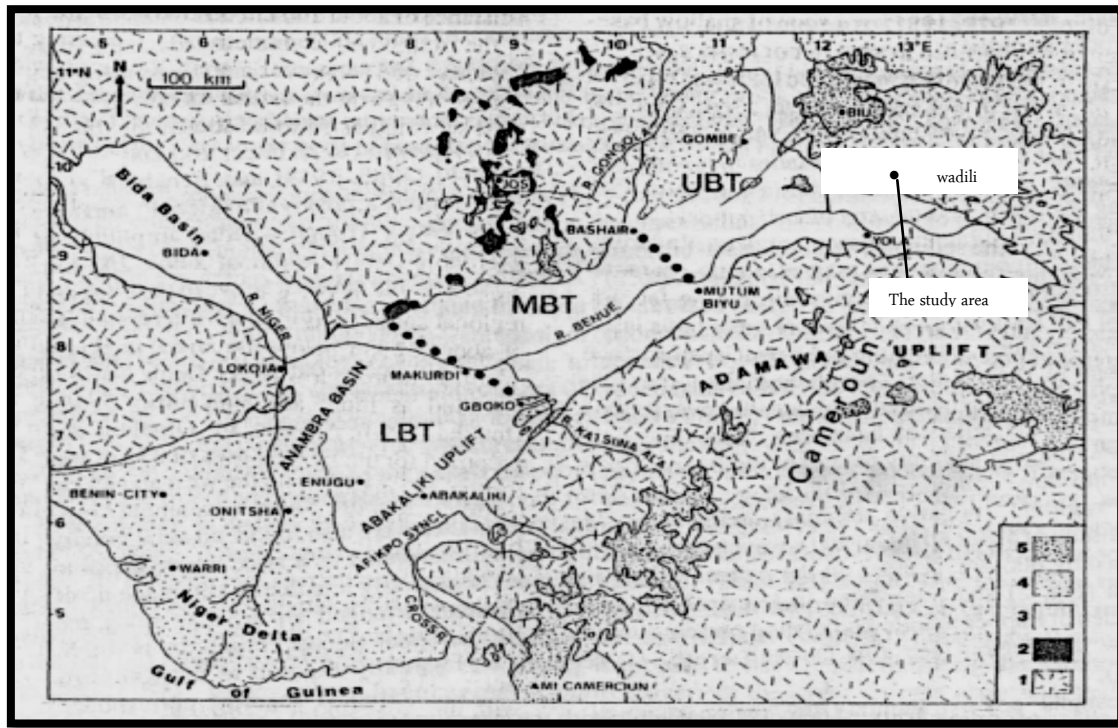


Fig.1: Outline geological Map of the Benue Trough of Nigeria, the study area and adjacent areas. LBT, lower Benue Trough; MBT, middle Benue Trough; UBT, upper Benue Trough. 1, Precambrian; 2, Jurassic “Younger Granite”; 3, Cretaceous sediment; 4, Post-Cretaceous sediment; 5, Cenozoic Recent basalts (including those of the Cameroun line).

Table 1: Major Element Oxide of Granite Rocks from Wadili Area, N.E Nigeria.

ROCK TYPE	GRANITES						Total	Average	Minimum	Maximum
Sample	L2S1	L6S1	D2L2	S1	L4S3	VL4S1				
SiO ₂	72.095	72.041	72.000	72.057	72.014	72.841	433.048	72.175	72.000	72.841
Al ₂ O ₃	6.691	6.832	6.784	6.739	6.903	6.602	40.554	6.759	6.602	6.903
K ₂ O	3.911	3.899	4.007	3.805	3.886	3.504	23.012	3.835	3.504	4.007
Na ₂ O	2.000	2.900	2.500	5.000	2.000	4.000	18.400	3.067	2.000	5.000
CaO	0.801	0.812	0.812	0.822	0.813	0.783	4.843	0.807	0.783	0.822
Fe ₂ O ₃	0.842	0.812	0.937	0.891	0.847	0.675	5.004	0.834	0.675	0.937
MgO	0.440	0.190	0.430	0.660	0.220	0.330	2.270	0.378	0.190	0.440
MnO	0.100	0.090	0.010	0.100	0.030	0.090	0.420	0.070	0.010	0.100
LOI	0.100	0.200	0.100	0.590	0.440	0.590	2.020	0.337	0.100	0.590

LOI means ‘Loss on Ignition’

Table 2: Rock designation on the basis of silica (SiO₂) content. After Hdman (1985)

Chemistry	Designation	Rock Type
32- 45% SiO ₂	Ultra-basic	Komatite
45-52% SiO ₂	Basic	Basalt, Gabbro
52-66% SiO ₂	Intermediate	Tonolite, Andesite, Dacite, Phonolite
66-75% SiO ₂	Acidic	Rhyolite, Granite

Table 3: Rock designation on the basis of Alumina (Al_2O_3) content. After Hyndman (1985)

Chemistry	Designation	Distinctive minerals
$\text{Al}_2\text{O}_3 > \text{Na}_2\text{O} + \text{K}_2\text{O} + \text{CaO}$	Peraluminous	Muscovite, Biotite, Corundum, Topaz, Garnet, Tourmaline
$\text{Al}_2\text{O}_3 > \text{Na}_2\text{O} + \text{K}_2\text{O} < \text{Na}_2\text{O} + \text{K}_2\text{O} + \text{CaO}$	Metaluminous	Hornblende, Epidote, Melilite, Biotite, Pyroxene.
$\text{Al}_2\text{O}_3 = \text{Na}_2\text{O} + \text{K}_2\text{O}$	Subaluminous	Olivine, Orthopyroxene, Clinopyroxene
$\text{Al}_2\text{O}_3 < \text{Na}_2\text{O} + \text{K}_2\text{O}$	Peralkaline	Sodic pyroxene, Sodic amphiboles, Astrophyllite, Columbite, Pyrochlore