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Research Article

Geochemical Classification of Miango Basalt of Jos Plateau State, Nigeria Using Numerical Analysis

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ABSTRACT:

Numerically, the formation of rock forming minerals from magma, depends on the numerical values of each mineral under thermodynamic conditions. This research was focused on geochemical classification of Miango basalt using numerical analysis. Findings have shown that, under mathematical context with Bowen's and Goldschmidt rules, the Miango basaltic sample of MIANGO VOLCANIC FIELD falls within gabbro clan and the estimated minerals using an empirical approach, are Ferro-augite (Basic Clino-pyroxene), Hortonolite (Basic olivine), Labradorite (Basic Plagioclase) and Ulvospinel (Iron ore). The gabbro clan includes basalt, dolerite, norite, scoria and gabbro and therefore empirically, Miango basaltic sample of MIANGO VOLCANIC FIELD was found to be characteristics of rock of Gabbro clan and the rock type for Miango basaltic sample in MIANGO VOLCANIC FIELD is Alkaline Olivine basalt magma type. Finally, the "mathematical connection" between Bowen's and Goldschmidt concepts was used in this research for a concise explanation of rock forming minerals from the beginning to the end of crystallization and would help the 'beginners' especially students of Earth sciences such as Geology, Mineralogy, Petrology and other chemical sciences such as Chemistry, Geochemistry and Petroleum Geology to have clear understanding of rock forming minerals from the Resident magma.

Keywords: *Numerical, Geology, Bowen, Goldschmidt, Basalt*

1.0: INTRODICTION

The occurrences of volcanic hills (cones) on the Jos Plateau in particular and Nigeria in general are indication of previous eruptive sites. The surface area of Nigeria is approximately 923,768 Km^2 and is underlain in nearly equal proportions by crystalline and sedimentary rocks with volcanic rocks dotting the central and northeastern portions. Volcanic rocks (acid/basic) are generally formed from solidifying magma or lava whether ejected or poured on the surface of the earth. There are three principal magma series recognized on the Earth with each composed of group of related magma types that are emplaced on the Earth's crust. They are: Basaltic (tholeiitic), Andesitic (calc-alkaline) and Rhyolitic (alkaline magma) series.

Application of mathematics to some aspect of sciences, such as physics, chemistry and other engineering disciplines has been successful over the years and several inventions have been made to solve scientific and engineering problems to enhance human comfort, but in the case of geology application of mathematics is not that much satisfactory and this research emphasizes on challenge arises using mathematical framework concerning the "problem of elemental substitution and distribution of chemical elements in igneous rocks throughout the time of crystallization from the beginning to the end of crystallization with mathematical foundation under thermodynamic change according Achuenu and others (2025). This research focuses on application of mathematical equations to Kassa Basaltic rocks of Jos Plateau state, Nigeria in connection with Bowen's and Goldschmidt concepts (Achuenu and others, 2025)

Geometrically, several minerals set in matrices and aggregate themselves in coordinate to form rocks and chemical elements of several properties bonded together to form minerals, which by definition is inorganically in composition with distinct chemical composition. Goldschmidt classified these elements according to their class of materials such as siderophile, lithophile and chalcophile elements as well as atmophile elements. But Mendeleev's (1914) arranged these elements in periodic table according to size and atomic mass. According to modern periodic law, atomic number

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increases from left to right and from top to bottom of periodic table. Therefore, the size and electronegativity of elements increase across the period and the size increases with decreasing electronegativity down the group. This pattern of modern periodic law would be used to explain how ions would enter into the lattice of a growing crystal during crystallization of silicate magma as a function of size and electronegativity. During crystallization of magma, temperature falls, with increasing content of silicon in the magma. This forms two series of reactions (Bowen's), one by interaction with magma, with the first mineral formed, to form minerals of different chemical composition, but with the same crystallographic structure. This is the case of solid solution in the magma. While the other, the first crystal to form, initially interact with the magma to form a solid with different crystallographic structure, and distinct chemical composition. This is the case of fractional crystallization in the magma.

The term solid solution and fractional crystallization are used simultaneously in this research to define the two series of reactions as stipulated by Bowen's reaction series.

2.0: LITERATURE REVIEW

2.1: INTRODUCTIO

Bowen's reaction principle a concept, first propounded in 1928 by Norman Bowen, which explains how mineral can respond to changing equilibrium conditions when a magma is cooled, by either a continuous diffusing – controlled exchange of elements with the magma or discontinuous melting of the material.

The periodic law was developed independently by Dmitri Mendeleev and Lothar Meyer in 1869. Mendeleev created the first periodic table and was shortly followed by Meyer. They both arranged the elements by their mass and proposed that certain properties periodically reoccur. Meyer formed his periodic law based on the atomic volume or molar volume, which is the atomic mass divided by the density in solid form. Mendeleev's table is noteworthy because it exhibits mostly accurate values for atomic mass and it also contains blank spaces for unknown elements.

Goldschmidt (1937) proposed his Classical general rules to explain the distribution of the elements, in which ions of similar size and charge substitute themselves.

Ringwood (1955) proposed the complementary use of the concept of electronegativity in order to understand the distributions of the chemical elements that could not be explained completely with the Goldschmidtian rules, especially when the minerals being investigated had high percentages of covalent bonding.

Nickold (1966) proposed that the tree principal factors (ionic size, Ionics charge and electronegativity) be expressed in a single function that would not result in the dichotomous predictions.

Bernard J. Wood (2003), Modifies Goldschmidt rules 2 and 3, that the site has a preferred radius of Ion (r) which eaters mostly easily, for ions of the same charge, those which are closest in radius to enter most easily, ions whi ch are larger or smaller are discriminated against.

Fournier and Rowe, (1966), state that silica Geothermomenter works because that solubility of the various silica minerals (Quartz, and chalcedony, S_iO_2) increase monotonically with temperature.

White (1970) state Na – K Geothermometer takes advantage of the fact that the equilibrium points of certain exchange reactions among various minerals, principally, the feldspar vary with temperature.

Spatial thinking is essential to all spatially dependent sciences, including geography. It comprises the spatial abilities of visualization, orientation and, likely also relation, although contested, (Bednarz & Lee, 2019).

2.2 Cenozoic Volcanic Province of Nigeria

Volcanic activity has taken place intermittently from Tertiary – Recent times in Nigeria (Kogbe, 1989). The most extensive outcrops are in Biu, Benue Trough, Longuda, and Mambilla Plateaux occupying the northeastern portion of Nigeria and on the Jos Plateau (Black *et al.,* 1985). The province is characterised by basement uplift just like most of the prominent volcanic provinces in Africa such as the Bameda Highlands, the Mambila Plateau, the Adamawa Plateau and numerous alkaline olivine basalts together with minor intrusives of trachytes and phonolites in the Benue Trough and Jos Plateau (Kogbe, 1989; Turner, 1983). These basaltic rocks which are found to either directly overlying the pre-existing Basement rocks and/or cross cutting both the Younger Granitic rock bodies are categorised into two main types (i.e. older and newer basalts) based on their age of emplacement and morphologies (Macleod *et al.,* 1971). The Older basalts are believed to have been formed during the Tertiary times and the newer basalts during the Quaternary. However comprehensive geochemical and geochronologic studies revealed that there are no differences between the Newer and Older basalts (CGG, 2014; Mohammed, 2014).

This volcanic activity in Nigeria which was basaltic in nature relative to acidic was the most widely spread and extends even to the southwest of Cameroon. The volcanic bodies occur as relics of volcanism in the form of scattered volcanic plugs, lava flows and cones in some places.

The Benue Trough which is about 1000 km long and 150 km wide is an intra-plate NE – SW rift depression, that has been genetically linked to the opening of the equatorial domain of the South Atlantic (Coulon *et al.*, 1996). Within the Benue Trough, relicts of previous volcanism are represented by volcanic cones and scattered plugs in some places with diverse composition (Mackay *et al.,* 1949; Nyako *et al.,* 2006; Turner *et al*., 1994).

As early as 22-11 Ma basic volcanic activity was recognized in the Upper Benue Trough particularly in the Biu Plateau region with the emplacement of trachyte and phonolite suites (Wright, 1985). A much later activity which was more widespread and predominantly alkaline in nature took place around 7 Ma (Meludu and Garde, 2003; Wright, 1985).

Field investigations have revealed that in the Biu Plateau (Upper Benue Trough) more than 50 volcanoes have been distinguished throughout the region. The volcanoes consist essentially of basaltic materials (Guiraud *et al.,* 1987; Lar *et al.,* 2007; Meludu and Garde, 2003). They occur in the form of tephra rings, cinder cones and maars composed of basaltic agglomerates, lava flows, volcanic bombs, ashes and tuffs. The basaltic flows overlie the Pan-African basement rocks or are interbedded in Cretaceous sediments in some places. They are believed to be emplaced during the Pliocene and Quaternary with bulk of them erupting from small vents or fissures and spreading over large areas (Guiraud *et al.,* 1987; Meludu and Garde, 2003; Turner, 1979; Wright, 1985).

The Biu volcanoes are divided into two main types based on their textures. Viz are: the Biu type - which is massive flow basalts with vesicles and the Maringa type - which is highly scoraceous and associated with pyroclastic deposits (Lar and Mohammed, 2012). However these two sub-types are mineralogically the same consisting of phenocrysts of both olivine, plagioclase (bytwonite-labradorite) and rarely pyroxene (diopside-augite) set in a groundmass of labradorite laths, magnetite, ilemnite, minor feldspars, nepheline and volcanic glass (Lar and Saidu, 2004). The lava flows and cinder cones were found to have xenoliths and pyroxene mega cryst inclusions in their mineralogy (Meludu and Garde, 2003). The volcanism in this area has been found to produce a number of volcanic cones that are aligned in a NNW – SSE direction with well-defined craters. They are simple and never in clusters but has very large craters (Caldera) of greater than 1 km (Lar *et al.,* 2007). The basalts in this area have been intensively weathered and eroded. This has been attributed to a break in activity which took place at the end of Pliocene (Wright, 1985). The occurrence of thin valley filling of basaltic flows and the youthful looking small cinder cones seems to signal the resumption of activity in the region during the Pleistocene (Wright, 1985).

The structural development or rejuvenation of major fault systems which took place during the Tertiary and in particular fractures at the contact between the Gongola branch of the Benue Trough and the Jos Plateau were found to be related to dominant E – W extension (Guiraud *et al.,* 1987). These faults/fractures appear to have controlled the localization of Neogene-Quaternary volcanism in the Upper Benue and Jos Plateau (Wright, 1969). Tertiary to Quaternary magmatism associated with these lineaments occurs as dykes, dolerite sills, alkaline volcanism and trachy-phonolite necks (Guiraud *et al.,* 1987; Wilson and Guiraud 1992). Volcanism of Pliocene age also occurs on the Jos Plateau and in the Cameroon volcanic line with their volcanic cones aligned/oriented in a NNW – SSE trending direction (Meludu and Garde, 2003; Wilson and Guiraud 1992; Wright, 1985).

Radiometric dating from ten (10) volcanic sites in the Biu area by Meludu and Garde (2003) using K –Ar method, gave ages of between 0.308 ± 0.012 Ma and 5.203 ± 0.208 Ma indicating a successive eruption. So older ages of some lava flows ranging between 140 ± 1.6 Ma – 106 ± 3.0 Ma were found within the Bima formation using Ar – Ar method (Baudin, 1991).

In the Middle Benue Trough, alkaline magmatism which is basic in nature appears to be widely distributed throughout the region. Manifestation of these basaltic rocks, lava flows; trachytes and phonolites are found occurring in the vicinity of Aghila, Awe, Keana, Kanje and Wase. These rocks occur as small volcanic cones, lava flows and plugs within the various rock formation across the Middle Benue Trough (Guiraud *et al.,* 1987; Kogbe, 1989). Some dolerite rocks have been dated between 87± 0.9 Ma – 47 ± 1.1 Ma by Baudin, (1991) which he interpreted as the age of low degree of metamorphism or hydrothermal activity in the Middle Benue Trough.

2.3 ORIGIN AND CLASSIFICATION OF BASALT.

Geologists have applied different names to different types of basalts for many years. One of the first major efforts was the distinction between the olivine (and alkali olivine) basalts, which yield an alkaline differentiation sequence, and tholeiites, which yield subalkaline trend, Kennedy (1933) and Tilley (1950). Yoder and Tilley (1962) applied the concept of separate alkali and sub alkali primary basalts which was explored in depth. Green and Ringwood (1967) also applied this principle. Bass (1972) further clarified the concept of basalts transitional between alkali and tholeiitic. MacDonald and Katsura (1964) proposed chemical distinction, rather than normative between alkali basalts and tholeiites. This classification was later challenged by McBirney and Williams (1964). A summary of various chemical characteristics of alkali olivine basalts was given by Schwarzer and Roger (1974).

Kuno (1968) introduced the term high alumina basalt, in addition to alkali and tholeiitic basalts as potential primary magma. This concept was also discussed by Kushiro and Kuno (1963). The term tholeiite has been modified in various ways. For example, Jakes and Gill (1970) distinguished tholeiites of mid-ocean ridges from the early island-arc tholeiite. Miyashiro, etal, (1969), discussed compositional variability of the mid-oceani ridge and described high-alumina varieties.

One of the earliest, still used, classification of igneous sequences was given by Peacock (1931). Peacock defined various terms, including calc-alkalic, which has been written as calcalkaline and calc-alkali. Kuno (1963), for example, originally identified pigeonite and hypersthenic series in Japan, he later re-classified these as tholeiitic and calcalkaline respectively. Kuno’s critical iron enrichment line, separated tholeiitic (iron-enriched) from calcalkaline (not iron-rich enriched) suites on aluminum, iron, magnesium diagram reproduced from Schwarzer and Rogers (1975). In recent years shoshonite and komatite were recognized. Shoshonites were originally described by Iddings (1895) as porphyritic rocks with a set of characteristics more recently summarized by Nicholls and Carmichael. Joplin (1968) adopted the term for certain High-K rocks. Her paper also distinguished among High-K shoshonites, high members of alkali basalt suites, and High-Na members of alkali basalt.

2.4 VOLCANIC ROCKS IN JOS PLATEAU

MacKay et.al, (1949) termed the Younger Cenozoic volcanic rocks of this area the Newer Basalt, but they divided them into” earlier group” and a “more recent group”. McLeod et.al, (1971) adopted similar plan, but used different terminology, which is the one used here. Flows and flow remnants lacking a well-defined volcanic focus were termed

Older Basalt, as distinct from the typically large valley-filling flows which can be traced to recognizable cones, the Newer Basalts.

Older Basalts are generally small, boundary remnants, most of which are demonstrably younger than the fluvio-volcanic series for the rest on erosion surface cut into the laterite, (McKay et.al, 1949 and McLeod et.al, 1971) and quite fresh. According to McLeod et.al, (1971) are dome like outcrops, especially in the southeast which may represent volcanic foci, (Falconer 1926). They are all basaltic, except for the remarkable "trachyte of Umat Hill near Bukkos, so far the only Cenozoic salic rock known on the plateau.

Newer Basalts as defined by McLeod et.al, (1971) cover some hundreds of square Km and extend to southwest of the Jos Plateau. They are mainly made of basaltic scoria and pyroclastic, including many fine volcanic bombs and have erupted a variety of inclusions.

Lava flows near some of the cones are underlain by basaltic ash deposits, over 7m this in places, especially in the region around Panyam.

2. 5 KASSA VOLCANIC FIELD

The Kassa volcanic basalt is one of the intraplate basaltic rocks on the Jos Plateau, north central Nigeria. It consists of about eight monogenetic volcanic cones overlying an area of about 66.6Km^2 and an erupted lava volume of about 45.5Km^2 based on geologic mapping and satellite image analysis. The volcanic centers constructed scoria cones and lava flows. The lava flows are mainly boulders of basaltic rocks, scoria and in some cases pumice, micro flow structures are part of these flows. Lar and Tsalha (2004) characterized the basaltic rocks in this area as alkaline basalt and grouped the basaltic rocks found in this area as Older and Newer Basalts and therefore, suggested that they erupted during the Quaternary to Tertiary times which is consist with the present work.

The petrographic study and microprobe analysis of basaltic rock in thin section revealed the presence of plagioclase laths and magnetite in ground mass, olivine (forsterite), clinopyroxene (diopside) and plagioclase phenocrysts (labradorite) and magnetite and/or ilmenite, (Tsalha and Lar, 2004).

3.0: MATERIAL AND METHODS

3.1: INTRODUCTION

This chapter discusses the procedure used in carrying out the survey and the subsequent analysis of the results obtained. It includes the description of the techniques used in compiling, collating and analyzing the data generated from the study. The procedures involve thin sectioning of the rocks, using to study rocks petrologic microscope under plane and cross-polarised light, chemical analysis using **ICPMS,** and mathematical computation.

3.3 METHODS

The procedures used for data collection are basically from primary source such as rock samples collected along Miango and Kassa volcanoes and secondary source, such as journals, internet, textbooks, etc. The following rock samples of gabbroic composition were collected and their compositions were used to classify them.

3.3.1 Field Mapping and Sample Collection

The study area covers a total area of about 4.5km^2 close to Kassa village from the south along Bukuru – Barkin ladi road to Heipang to the North. The area falls within Naraguta Sheet 168SE, mapped on a scale of 1:10,000. The dominant rock types encountered are: basalts, Older granites, Younger granites and sediments. The Basalts are divided into: Older basalts, Newer basalts and lateralized basalts. The following rock samples of gabbroic composition were collected and their compositions are used to classify them and these are shown in Plate 1 below.

- Basalt
- Volcanic agglomerate
- Volcanic ash

PLATE 1: Showing Volcanic Agglomerate at Miango

3.4: METHODS ADOPTED IN THIS RESEARCH

Achuenu and others (2025) uses this mathematical equation below to calculate the numerical values of all the minerals in rocks with respect to thermodynamics and thisgiven as;

$$\sum_{n=0}^{p}\binom{n}{p}[\beta-\alpha]_{n+p}(Z_0)_{\overline{\delta}} = \binom{n}{p}\left[\beta_{n-p}\alpha_p\right](Z_0)_{\overline{\delta}}$$

Where Z_0 is the silicate identity and

$$\boldsymbol{\eta} = \frac{z^-}{x^+} \text{ (ionic spacies)}$$

'$\boldsymbol{\eta}$' is the strength of the magma $\mathfrak{W}$, which is the ratio of the silicate radical z^- to that of cation x^+ under electrolytic condition and 'p' is the recipient cation which depends on '$\boldsymbol{\eta}$'.

$\binom{n}{p}$ Is the coefficient of rock forming minerals and it determines the number of outcomes of each mineral in the melt $\mathfrak{M}(Z_0)_{\overline{\delta}}$.

3.4.1: Mathematical connection between Bowen's and Goldschmidt concept using Binomial Expansion (Achuenu and others, 2025)

Therefore for;

$$\sum_{n=0}^{p}\binom{n}{p}[\beta-\alpha]_{n+p}(Z_0)_{\bar{\delta}} = \binom{n}{p}[\beta_{n-p}\alpha_p](Z_0)_{\bar{\delta}}$$

$$\sum_{n=r}^{p}\binom{n}{p}[\beta-\alpha]_{n+p}(Z_0)_{\bar{\sigma}} = \binom{n}{p}[\beta_{n-p}]\alpha_0(Z_0)_{\bar{\sigma}} - \binom{n}{p}[\beta_{n-p}]\alpha_1(Z_0)_{\bar{\sigma}} + \binom{n}{p}[\beta_{n-p}]\propto_2(Z_0)_{\bar{\sigma}}$$

Mathematically, in complex analysis;

$$i^2 = -1$$

$$\sum_{n=r}^{p}\binom{n}{p}[\alpha+\beta]_{n+p}(Z_0)_{\bar{\delta}} = [\boldsymbol{\beta}_n](Z_0)_{\bar{\delta}} + i\{[\boldsymbol{\beta}_{n-p}\alpha_p](Z_0)_{\bar{\delta}}\} + [\propto_p](Z_0)_{\bar{\delta}}$$

'

i' is a complex number in silicate Magma.

$$({}^nc_p,) = \binom{n}{p}$$

$$\binom{n}{p} = \frac{n!}{(n-p)!\,p!} \quad and \quad 0! = 1$$

$\boldsymbol{\delta}$ = o, p, a, m and f

Where, o, p, a. and m are olivine, pyroxene, amphibole, mica and feldspar

Magma with no water content at high temperature, silica deficient and low viscosity.

3.5: ANHYDROUS MELT, 𝕸.

3.5.1: Mathematical expression for Mafic Olivine series: $(\boldsymbol{\beta}_{2-p}\alpha_p)(Z_0)_{\bar{\sigma}}$

$$\sum_{n=r}^{p}\binom{2}{0}[\alpha+i\beta]_2(Z_0)_{\bar{\sigma}} = 1[\beta_2](Z_0)_{\bar{\sigma}} - 2[\beta_1 \propto_1](Z_0)_{\bar{\sigma}} + 1[\propto_2](Z_0)_{\bar{\sigma}}$$

Given that, $\beta = Magnesium$

$\propto = Iron$

Y = Calcium, Chromium, Nickel or Manganese

$(Z_0)_{\bar{\sigma}} = Si\,O_4$

From equation above, we can rewrite it as;

$$\sum_{n=r}^{p} \binom{2}{0} [\alpha + i\beta]_2 \; Si\, O_4 = \; 1\, Mg_2 \; SiO_4 \; + i\{2[\text{MgFe}]\, SiO_4\} + 1\, Fe_2 Si\, O_4$$

$$[\text{Mg} + \text{iFe}]_2 \; Si\, O_4 \; = Mg_2\, Si\, O_4 \; + i[Mg\, \text{Fe}]Si\, O_4 + i[\text{MgFe}]SiO_4 \; + Fe_2\, Si\, O_4$$

$$\sum_{n=r}^{p} \binom{2}{0} [Mg + iFe]_{n+p}\, Si\, O_4 = \; Forsterite + i[Hyalosiderite] + i[Hortonolite] + Fayalite$$

According to Achuenu and others (2025), $Mg_{2-p}Fe_pSiO_4$ is an **'<u>Olivine series</u>'** formula that can be used to

calculate all olivine minerals from the melt **𝖂**, where p is an integer and ranges from 0 to 2 in olivine crystals. At p equals to zero, 100% Forsterite (Fo) crystallizes with chemical formula of Mg_2SiO_4 and at p equals to 2, Forsterite (fo) disappears and 100% of pure Fayalite (Fa) crystallizes with chemical formula of $Fe_2SiO_{4(s)}$. Therefore forsterite, *Hyalosiderite* , Hortornolite and fayalite are the primary olivines in the mafic olivine series.

3.5.2: Expected Mathematical Expression for Mafic Pyroxene series: $[\boldsymbol{\beta}_{2-p}\alpha_p](Z_0)_{\bar{p}}$

$$\sum_{n=r}^{p} \binom{2}{0} [\beta + \alpha]_{2+p}\, Si_2O_6 = 1\, Mg_2\, Si_2O_6 + i[2(\text{MgFe})Si_2O_6] + \; Fe_2\, Si_2O_6$$

$$\sum_{n=r}^{p} \binom{n}{p} [\beta + \alpha]_{n+p}\, Si_2\, O_6 \; = Mg_2\, Si_2\, O_6 \; + i[Mg\, \text{Fe}]\, Si_2 \; O_6 + i[\text{MgFe}]Si_2\, O_6 \; + Fe_2\, Si_2\, O_6$$

Pyroxene = Enstatite +Magnesio-hypersthene + Ferro-hypersthene + Ferrosilite

$Mg_{2-p}Fe_pSi_2O_6$ is a pyroxene series, where p range from 0 to 2 in pyroxene. At p equals to zero, 100% Enstatite (En) crystallizes with chemical formula of $Mg_2Si_2O_6$ and at p equals to 2, Enstatite disappears and 100% of pure Ferrosilite crystallizes with chemical formula of $Fe_2Si_2O_6$ Therefore Enstaite, Hypersthene, Eulite and ferrosilite are the primary pyroxenes in the mafic pyroxene series.

3.6: Expected Mathematical Expression for Plagioclase series: $(\Upsilon_{m-p}X_p)(\mathcal{Q}_{x-y}\mathcal{N}_y)\mathcal{W}_i$

$$(\Upsilon + X)_{x+y}\, (\mathcal{Q} + \mathcal{N})_{m+p}\, \mathcal{W}_i = (\Upsilon_{m-p}X_p)(\mathcal{Q}_{x-y}\mathcal{N}_y)\mathcal{W}_i$$

$$[X_{m-p}\Upsilon_p]Zi = [X_{1-p}\Upsilon_p](Z_0)_{\bar{f}}2$$

$$= [X_{m-p}\Upsilon_p](Z_0)_{\bar{f}}2$$

$$(Z_0)_{\bar{f}} = S_iO_4$$

$$(Z_0)_{\bar{f}}2 = S_{i\,4}O_8$$

$$\Upsilon - \text{Position} = \Upsilon + X$$

$$[\Upsilon_{m-p}\Upsilon_p](Z_0)_{\bar{f}}2 = [X_{1-p}\Upsilon_p]\,[\mathcal{Q}_{4-y}\mathcal{N}_y]\,\mathcal{W}_i$$

For p = 1 and y =1

$$[X_{1-p}\Upsilon_p]\,[\mathcal{Q}_{4-y}\mathcal{N}_y]\,\mathcal{W}_i = [X_{1-1}\Upsilon_1]\,[\mathcal{Q}_{4-1}\mathcal{N}_1]\,\mathcal{W}_i$$

$$[X_{1-p}\Upsilon_p]\,[\mathcal{Q}_{4-y}\mathcal{N}_y]\,\mathcal{W}_i = [\Upsilon_1]\,[\mathcal{Q}_3\mathcal{N}_1]\,\mathcal{W}_i$$

$$\Upsilon_m\,[\mathcal{Q}+\mathcal{N}]_{x+y} + [x]_p(\mathcal{Q}+\mathcal{N}))]_{x+y} = [X_{1-p}\Upsilon_p]\,[\mathcal{Q}_{4-y}\mathcal{N}_y]\,\mathcal{W}_i$$

$\Upsilon_m\,[\mathcal{Q}+\mathcal{N}]_{x+y} + [x]_p(\mathcal{Q}+\mathcal{N}))]_{x+y}$ is called "***<u>PLAGIOCLASE SERIES</u>***"

$$\Upsilon_m\,[\mathcal{Q}+\mathcal{N}]_{x+y} + [x]_p(\mathcal{Q}+\mathcal{N}))]_{x+y} = CaAl_2Si_2O_8 + NaAlSi_3O_8$$

Equation (87), is used to solve the problem involving couple substitution in felsic rock.

3.7: APPLICATION OF METRICAL MATRICES TO ROCK FORMING MINERALS

3.7.1: Metrical Matrix for Mafic Olivine and Feldspars;

Then set equations (105) and (110) in matrices form.

$$[\Upsilon_1(\mathcal{Q}_2\,\mathcal{N}_2)]0_8 + X_1(\mathcal{Q}_3\,\mathcal{N})0_8 = [(1,\ 0],[2,\ 0)] + [(0,\ 1],[3,\ 1)]$$

$$[\beta_2](Z_0)_{\bar{o}} + [\alpha_2](Z_0)_{\bar{o}} = [2,\ 0] + [0,\ 2]$$

$$\begin{bmatrix} Anorthite \\ Forsterite \end{bmatrix} + \begin{bmatrix} Albite \\ Fayalite \end{bmatrix} = \begin{bmatrix} Anorthoclase \\ Olivine \end{bmatrix}$$

3.7.2: Metrical Matrix for Mafic Pyroxene and Feldspar

$$\begin{bmatrix} Ca_1[Al_2\,Si_2]0_8 \\ [Mg_2]\,Si_2O_6 \end{bmatrix} + \begin{bmatrix} Na_1[AlSi_3]0_8 \\ [Fe_2]\,Si_2O_6 \end{bmatrix} = \begin{bmatrix} (Ca_1Na_1)Al_3\,Si_5]0_{16} \\ [MgFe]\,Si_2O_6 \end{bmatrix}$$

$$\begin{bmatrix} Anorthite \\ Enstatite \end{bmatrix} + \begin{bmatrix} Albite \\ Ferrosilite \end{bmatrix} = \begin{bmatrix} Anorthoclase \\ Pyroxene \end{bmatrix}$$

4.0 RESULTS AND DISCUSSION

4.1 Chemical Classification of the Miango Basaltic Rocks

The Miango basaltic rocks are classified using their major oxide compositions and this shown in Table 1 below. The SiO_2 contents range between 45.8–52.4 wt %, while total alkalis (Na_2O + K_2O) vary from 3.1–5.7 wt %, indicating a mildly alkaline character.

The Fe_2O_3/MgO ratios (1.6–2.3) and TiO_2 > 1 wt % further suggest a transitional to alkaline affinity, typical of **intraplate continental basalts**. The classification aligns with the **tholeiitic–alkaline basalt spectrum** of Yoder and Tilley (1962) and corresponds to basaltic magmas derived from a heterogeneous upper-mantle source that experienced limited fractional crystallization prior to eruption.

Based on the chemical analyses and the examination under thin section, Kassa basalts are classified into alkaline, olivine basalt magma type and tholeiite magma type

1. **OLIVINE BASALT MAGMA TYPE:** The essential minerals are olivine, augite, basic plagioclase, and iron ore. The pyroxene is a Diopside or basaltic augite often a titaniferous variety.

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2. **THOLEIITE BASALT MAGMA TYPE**: The essential minerals are pyroxene, basic plagioclase and iron ore. Olivine is either completely absent or present in very subordinate amount. The pyroxene belongs typically to the enstatite – augite (pigeonite) series of lime - poor pyroxene.

Yoder and Tilley (1962, p.355) comment that in alkali basalts the total alkalis usually exceed 3%. In some siliceous tholeiites the alkalis exceed 3%, whereas some silica-poor alkali basalts contain less than 3% total alkalis. Therefore, alkali basalt contains normative olivine and nepheline that is $3\%<Ne<5\%$. Ne > 5% is called Basanite. Tholeiite basalt contains less than 5% modal olivine, tholeiite olivine basalt contains greater than 5% modal olivine and alkali basalt contains less than 5% modal olivine. The tholeiite basalt is characterized by the existence of reaction relation between the Mg

Olivine and Ca-poor pyroxene, namely orthopyroxene and pegionite (Tilley, 1950, Kuno etal, 1957). Therefore, Mg olivine is usually absent from the ground mass of volcanic rock, where present, it is surrounded by the reaction rims of pegionite provided that the groundmass is reasonably crystalline. Alkali olivine basalt is characterized by the absence of reaction relation between olivine and pyroxene (Tilley, 1950 Kuno etal, 1957), olivine is invariably present in the groundmass.

Table 1: Chemical and mineralogical composition of MAI Sample in Miango Volcanic Field

Table 1: Chemical and mineralogical composition of MAI

Chemical Composition (in weight percent)[a]	
SiO_2	52
Al_2O_3	15
Fe_2O_3	12
FeO	
MgO	6
CaO	7
Na_2O	3
K_2O	2
TiO_2	2
P_2O_5	0.6
MnO	0.00
	99.93

Mole (in volume percent)

Mineralogical Composition (in weight percent)[a]	
Olivine	35
Clinopyroxene	10
Plagioclase	30
Opaque Minerals	
Glass	25

4.3: Application of Numerical Principles to Geology of Miango Volcanic Basalt of Jos Plateau State.

1. Petrographic study of Miango rock Sample of Jos Plateau state.

The rock samples that were collected from MIANGO Volcanic Field were prepared into thin Section and studied under petrologic microscope. Observations as the rock characteristics were made under plane and cross polarized light. Details of the observations made are given below.

Miango Rock Sample:

- Texture: fine grained rock with presence of vesicles
- Colour: dark to grey
- Mineral composition: plagioclase, olivine and pyroxene are the main minerals with no quartz. Iron ore is also present.

Miango Basaltic Slide

Texture: Phenocrystals of olivine and Augite with euhedral to subhedral shapes as shown in Slides 1 and 2 below.

>30% Phenocrysts consisting:

> 20% Ol and < 10% Aug

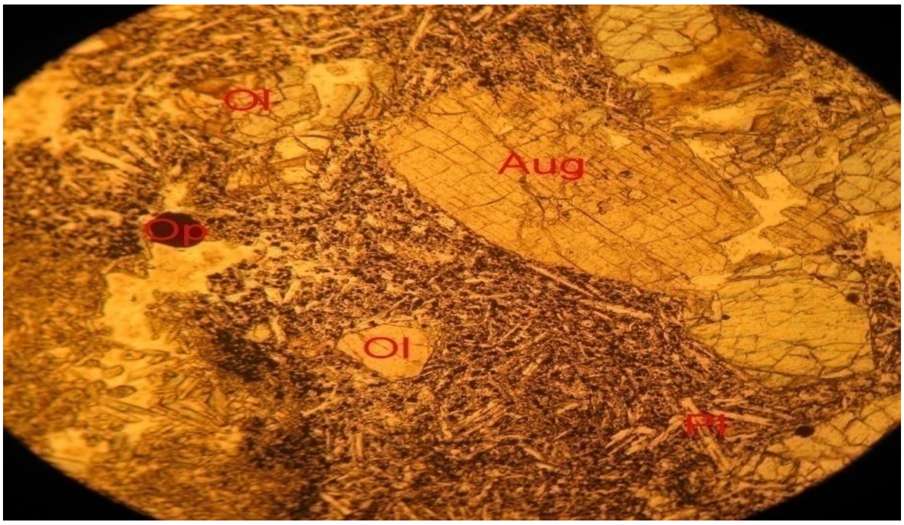
< 70% Groundmass (Neglecting Vesicles) consisting:

> 30% Pl which are needle-like laths showing slight alignment in a common plane

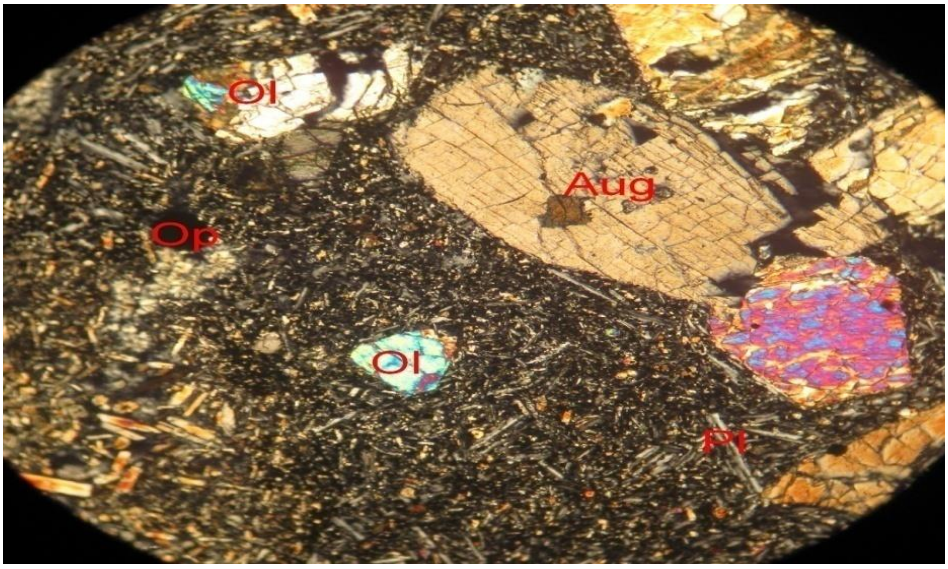
> 15% Ol + Aug

< 25% tiny opaque (magnetite?)

Crystallinity: Hypocrystalline.



Slide 1: Photomicrograph of Miango basalt, PPL phenocrystals of olivine and augite



Slide 2: Photomicrograph of Miango basalt, XPL phenocrysts of olivine and augite

4.4: Mathematical Analysis of Mafic, Felsic and Ferrous/Ferric Minerals of Miango basalt in Miango Volcanic Field.

In **Miango Volcanic Field,** the expected rock type of **Miango basalt** is "**Alkali Olivine basalt**" because the modal olivine as observed under microscope both plane and crossed polarized light is greater than **5%** as seen in Table 3 above and the total alkali content analysed using ICP-MS exceeds **3%** as seen in Table 4 above and as commented by Yoder and Tilley (1962, p. 355). The compositions of alkali olivine basalt of **Miango basalt** include;

1. Plagioclase, **Labradorite. (30%)**
2. Olivine, **Hortonolite (35%)**
3. Pyroxene, **Augite (10)**
4. Iron ore, **Ulvospinel,** which is titanite granular magnetite (**25%**).

Alkali olivine basalt is likely to be produced by the partial melting of the upper mantle material at the depth of about 80km and an average temperature of 1250^0C.

Olivine crystallizes first, as the first fraction. It forms with its silicon arranged in isolated tetrahedrons of SiO_4 with a general chemical formula of **$(MgFe)_2SiO_4$** ranging from **Mg_2SiO_4** (forsterite) to **Fe_2SiO_4** (fayalite), olivine has proportions of one-part silicon to two parts iron or magnesium [1:2 ratios], which means it depletes the magma of iron and magnesium and leaves the remaining liquid with proportionately more silicon. Olivine has a general molecular formula of **$(\beta_{2-p}\alpha_p)Z_0$** and when the sample of **Miango basalt** collected from Miango volcanic basalt observed under thin section, its modal percentage composition is (**35%**) as shown in Table 4 above.

Pyroxene has a general molecular formula of **$(\beta_{2-p}\alpha_p)Z_0$** and when the sample of **MIA** collected from Kassa volcanic basalt observed under thin section, its modal percentage composition is (**10%**) as shown in Table 1 above.

4.4.1: Empirical formula and classifications for Mafic Oxides of Olivine of Miango basalt in Miango Volcanic Field using Zero Polynomial of $(\beta_{2-p}\alpha_p)(Z_0)_{\bar{o}}$

Table 4 above, represents the chemical compositions of Oxides of Olivine of MIA as analyzed using ICP-MS and can be mathematically analyzed using empirical formula below;

A: **Empirical Formula for the Mafic Oxides of Olivine of Miango basalt**

Therefore, the volume percent of Mafic Oxides in KIA1 are;

MgO = **6.0%** in **Miango basalt**

FeO = **12.0%** in Miango basalt

SiO_2 = **52.0%** in Miango basalt

6% + 12% + 52.0% = 70.0%

Therefore, the chemical compositions of mafic oxides of Olivine can be expressed using empirical formula as shown Table 2 below.

Table 2: Empirical Formula for the Mafic Oxides of Olivine of Miango basalt.

Oxides of the mineral	MgO	FeO	SiO_2
% composition of the Oxides	**8**	16	**75**
Molar mass of the Oxides	**40**	**68**	**60**
$\frac{\%composition}{Molar\ mass}$	$\frac{8}{40}$	$\frac{16}{68}$	$\frac{75}{60}$
Ratio of the Oxides	**0.217**	**0.256**	**1.25**
Divide by the smallest number	$\frac{0.217}{0.217}$	$\frac{0.256}{0.217}$	$\frac{1.25}{0.217}$
	1	**1.2**	**5.8**
	5	**6**	**29**
	$(MgO)_5$	**$(FeO)_6$**	**$(SiO_2)_{29}$**
	Mg_5O_5	**Fe_6O_6**	**$Si_{29}O_{58}$**
Empirical formula of the Oxides	**$(Mg_5Fe_6)O_{11}$**		**$Si_{29}O_{58}$**

Chemical formula of the mineral	**$(Mg_5Fe_6)\ Si_{29}O_{69}$**
Mineral 1	**Olivine**
Mineral 1 + SiO_2	**$(Mg_5Fe_6)\ Si_{30}O_{71}$**
Mineral 2	**Pyroxene**

a. $(Mg_6Fe_5)Si_{29}O_{69}$ can be converted to true value of Olivine Mineral using Zero polynomial of $Mg_{2-p}Fe_pSiO_4$

Therefore;

$Mg_{2-p}Fe_pSiO_4$ = **$(Mg_5Fe_6)Si_{29}O_{69}$**

$Mg_{2-p}Fe_pSiO_4$ = **$(Mg_9Fe_{11})\ (SiO_4)_{10}$**

$(Mg_{11}Fe_9)\ (SiO_4)_{10}$ = 35%(Hortonolite)

100% (Hortonolite) = **45%(Forsterite)** + **55%** (**Fayalite**) as shown in Table 7a, above.

Therefore, For 35%(Hortonolite)

35% (Hortonolite) = **16%(Forsterite)** + **19%** (**Fayalite**) **of MIA** in **Kassa Volcanic Field**

b. $(Mg_6Fe_5)Si_{29}O_{69}$ can be converted to real value of Olivine Mineral using Binomial Expansion of $Mg_{2-p}Fe_pSiO_4$

$$\sum_{p=r}^{n} \binom{2}{0} [\alpha + i\beta]_2\ Si\ O_4 \ = \ 1\, Mg_2\ SiO_4 + i\{2[\text{MgFe}]\, SiO_4\} + 1\, Fe_2Si\ O_4$$

$(Mg_6Fe_5)Si_{29}O_{69}$ can occur in two different ways provided that, the theory of zero polynomial is satisfied during crystallization of magma, either;

$Mg_{10}Fe_{10}Si_{10}O_{40} = Mg_{11}Fe_9Si_{10}O_{40}$

Or

$Mg_{10}Fe_{10}Si_{10}O_{40} = Mg_9Fe_{11}Si_{10}O_{40}$

$[Mg+iFe]_{20}Si_{10}O_{40} = Mg_{20}Si_{10}O_{40} + i[Mg_{11}Fe_9]Si_{10}O_{40} + i[Mg_9Fe_{11}]Si_{10}O_{40} + Fe_{20}Si_{10}O_{40}$

$Mg_{11}Fe_9Si_{10}O_{40}$ = Hyalosiderite

$Mg_9Fe_{11}Si_{10}O_{40}$ = Hortonolite

B: Classification of Mafic Olivine of Miango basalt in Miango Volcanic Field

- **Olivine class** = 1[basic '**Olivine**'] + [intermediate '**Olivine**'] + i[acidic **Olivine**].
- **Olivine Minerals** = [basic '**Forsterite]** '+ i[intermediate'**Hyalosiderite**'] + i[intermediate '***Hortonolite*** '] acidic
- '***Fayalite***'

['**Hortonolite** '] = [intermediate '**Olivine**']
['**Miango basalt** '] = [intermediate '**Hortonolite**']
['**Miango basalt** '] = [intermediate '**Olivine** ']

$Mg_{2-p}Fe_pSiO_4$ is an **'Olivine series'** formula that can be used to calculate all olivine minerals from the melt $\mathfrak{W}$, where p is an integer and ranges from 2 to 0 in olivine crystal. At certain value of p, Hyalosiderite crystallizes with chemical formula of **$\underline{(Mg_9Fe_{11})Si_{10}O_{40}}$**. Therefore **35%** of **<u>Hortonolite</u>** is the primary olivine in the mafic olivine series of **Miango basalt**.

4.4.2: Empirical formula and classifications for Mafic Oxides of <u>Clino-pyroxene</u> of Miango basalt in Miango Volcanic Field using Zero Polynomial of $(\beta_{2-p}\alpha_p)(Z_0)_{\bar{p}}$

Table 4 above, represents the chemical compositions of Oxides of Pyroxene of MIA as analyzed using ICP-MS and can be mathematically analyzed using empiric al formula based on percentage of Calcium Oxide in Kassa Basalt below;

CaO = 10%, MgO = 9%, FeO = 16%

Therefore, the chemical compositions of mafic oxides in Pyroxene can be expressed using empirical formula as shown Table 3 below.

Table 3: Empirical Formula for the Mafic Mineral Oxides in Miango basalt

Oxides of the mineral	MgO	FeO	CaO	SiO_2
% composition of the Oxides	9	16	10	67
Molar mass of the Oxides	40	68	56	60
$\frac{\%composition}{Molar\ mass}$	$\frac{8}{40}$	$\frac{16}{68}$	$\frac{9}{56}$	$\frac{67}{60}$
Ratio of the Oxides	0.2	0.24	0.16	1.11
Divide by the smallest number	$\frac{0.2}{0.16}$	$\frac{0.24}{0.16}$	$\frac{0.16}{0.194}$	$\frac{1.11}{0.194}$
	1.2	1.4	1	5.7
	6	7	5	28
	$(MgO)_6$	$(FeO)_7$	$(CaO)_5$	$(SiO_2)_{28}$
	Mg_6O_6	Fe_7O_7	Ca_5O_5	$Si_{28}O_{56}$
Empirical formula of the Oxides	$(Mg_6Fe_7Ca_5)O_{18}$			
Chemical formula of the mineral	$(Mg_6Fe_7Ca_5)Si_{28}O_{74}$			
Mineral 1	Calcic- Olivine			
Mineral 1 + SiO_2	$(Mg_6Fe_7Ca_5)Si_{29}O_{76}$			
Mineral 2	Calcic- Pyroxene			

a. $(Ca_5Mg_6Fe_5)Si_{29}O_{74}$ can be converted to true value of calcic -Pyroxene Mineral using Zero polynomial of $Mg_{2-p}Fe_pSi_2O_6$

Therefore;

From,

$\Upsilon[Z_0(\beta, \alpha)] = \Upsilon[Z_0(\beta+\alpha)]$

$[Ca(Mg+Fe)_\eta]\ Si_{20}O_{60} = \mathbf{(Ca_5Mg_6Fe_7)Si_{30}O_{76}}$

$\mathbf{(Ca_{0.6}Mg_{0.6}Fe_{0.8})Si_2O_6} = [(Ca_5Mg_6Fe_7)]\ \mathbf{Si_{29}O_{74}}$

$\mathbf{(Ca_6Mg_6Fe_8)Si_2O_6} = [(Ca_5Mg_6Fe_5)]\ \mathbf{Si_{29}O_{74}}$

$\mathbf{(Ca_6Mg_6Fe_8)Si_{20}O_{60}} = [(Ca_3Mg_3Fe_4)]\ \mathbf{Si_{10}O_{30}}$

$\mathbf{(Ca_5Mg_6Fe_7)Si_{29}O_{76}} = [(Ca_3Mg_3Fe_4)]\ \mathbf{Si_{10}O_{30}}$

$[Ca(Mg+Fe)_\eta]\ Si_{20}O_{60} = [(Ca_3Mg_3Fe_4)]\ \mathbf{Si_{10}O_{30}}$

$[(Ca_3Mg_3Fe_4)]\ \mathbf{Si_{10}O_{30}}$ = Calcic-Pyroxene

: $[(Ca_3Mg_3Fe_4)]\ \mathbf{Si_{10}O_{30}}$ {**CaO = 30%, MgO = 40%, FeO = 30%**}

Therefore;

Fore, **Ca = 30% (20%<Ca<45%)**

Mg: Fe = 70%

Mg = 40%, Fe = 30%u

$[Mg_{40}: Fe_{30}] = 70\%$

$Ca_{30}[(MgFe)_{70} = 100\%$

Then;

From $\Upsilon[Z_0(\boldsymbol{\beta}, \alpha)] = \Upsilon[Z_0(\boldsymbol{\beta}+\alpha)]$

$[\Upsilon(\boldsymbol{\beta}+\alpha)]Z_p = [(\Upsilon, \boldsymbol{\beta})]Z_p + [(\Upsilon, \alpha)]Z_p$

Then;

$[\Upsilon(\boldsymbol{\beta}+\alpha)]Z_p \sim 100\%$

$[\Upsilon_{30}(\boldsymbol{\beta}+\alpha)_{70}]Z_p = [(\Upsilon_{40}, \boldsymbol{\beta}_{30})]Z_p + [(\Upsilon_{30}, \alpha_{30})]Z_p$

$Ca_{30}[(Mg_{30}: Fe_{40})]Z_p = Ca_{30}[(Mg_{30} + Fe_{40})]Z_p$

$Z_p = Si_{10}O_{30}$

$[Ca_{30}(Mg+Fe)_{35}]\ Si_{20}O_{60} = [(Ca_{30}Mg_{70})]\ Si_{100}O_{300} + [(Ca_{30}Fe_{70})]\ Si_{100}O_{300}$

$[Ca_{30}(Mg+Fe)_{35}]Si_{100}O_{300}=[(Ca_{30}Mg_{70})]Si_{100}O_{300}+[(Ca_{30}Fe_{30}Mg_{40})]Si_{100}O_{300}+ [(Ca_{30}Fe_{40}Mg_{30})]\ Si_{100}O_{300} + [(Ca_{30}Fe_{70})]\ Si_{100}O_{300}$

FERRO-AUGITE SERIES = $[(Ca_{30}Fe_{40}Mg_{30})]Si_{100}O_{300}$

FERRO-AUGITE = 10% **$[(Ca_3Fe_4Mg_3)]Si_{10}O_{30}$**

Diopside = $[(Ca_3Mg_7)]Si_{10}O_{30}$

Hedenbergite = $[(Ca_3Fe_7)]Si_{10}O_{30}$

$(Wo_3En_4Fe_3) = 10$

$Wo_{30}\ En_{40.}Fe_{30} = 100\%$

100% (Augite) = **30%(Diopside)** +20%(Magnesio-**augite**) +20%(Ferro-**augite**) + **30%** (**Henderbergite**) as shown in Table 10a, above.

Therefore, For 10%(Augite)

10% (Augite) = **1.5%(Diopside)** + 3%(Magnesio-**augite**) + 4%(Ferro-**augite**) + **1.5%** (**Henderbergite**) **of Miango basalt** in **Miango Volcanic Field**

B: Classification of Mafic Clino-Pyroxene of Miango basalt in Miango Volcanic Field.

- **Clino-pyroxene classes** = 1[basic 'Clino-**pyroxene**'] + [intermediate 'Clino-**pyroxene**'] + i[acidic Clino-**pyroxene**].
- Clino-py**roxene classes** = 1[basic '**magnesio-augite**'] + [intermediate '**augite**'] + i[acidic **Ferro-augite**].
- **Clino-pyroxene**=[basic'**Augite**']+i[intermediate'**Augite**'] +i[acidic '**Augite**']

['Ferro-**augite** '] = ['**Clino-pyroxene**']

['**Miango basalt**'] = ['Ferro-**Augite**']

['**Miango basalt** '] = ['**Clino-pyroxene**']

$Mg_{2-p}Fe_pSi_2O_6$ is a **'Pyroxene series'** formula that can be used to calculate all Pyroxene minerals from the melt 𝖂, where p is an integer and ranges from 0 to 2 in Pyroxene crystals. At certain value of p, Hypersthene and Augite crystallize depending on their stability fields with chemical formula of **$(Mg_6Fe_7)Si_{30}O_{76}$** and **$[(Ca_3Fe_4Mg_3)]Si_{10}O_{30}$**. Therefore (**4%**) of **Ferro-augite** is the secondary calcic - Pyroxene called **CLINO-PYROXENE** in the mafic olivine series of Miango Volcanic Field

4.4.3: Empirical formula and classifications for Felsic Oxides of Miango basalt in Miango Volcanic Field using Zero Polynomial of $(\Upsilon_{1-p}X_p)\ (Q_{4-y}\mathcal{N}_y)\mathcal{W}_i$

Table 1 above, represents the chemical compositions of Oxides of felsic mineral of Miango basalt as analyzed using ICP-MS and can be mathematically analyzed using empirical formula below;

A: **Empirical Formula for Felsic Oxides of Miango basalt**

Therefore, the volume percent of Felsic Oxides of Miango basalt are;

CaO = **7%** in Miango basalt

Al_2O_3 = **15%** in Miango basalt

Na_2O = **3%** in Miango basalt

SiO_2 = **52.0%** in Miango basalt

7% + 15% +3+ 52.0% = 77%

The Total volume percent of Felsic Oxides of KIA1 = 77%

CaO% + Na_2O+ Al_2O_3% + SiO_2 % = Plagioclase %

CaO = **9%** in Plagioclase

Al_2O_3 = **20%** in Plagioclase

Na_2O = **4%** in Plagioclase

SiO_2 = **68%** in Olivine

Therefore, the chemical compositions of felsic oxides in Olivine can be expressed using empirical formula as shown Table 4 below.

Table 4: Empirical Formula for the Felsic Oxides in Miango basalt

Oxides of the mineral	**CaO**	**Na_2O**	**Al_2O_3**	**SiO_2**
% composition of the Oxides	**9**	3	**20**	**68**
Molar mass of the Oxides	**56**	**62**	**100**	**60**
$\frac{\%composition}{Molar\ mass}$	$\frac{9}{56}$	$\frac{4}{62}$	$\frac{20}{100}$	$\frac{68}{60}$
Ratio of the Oxides	**0.161**	**0.065**	**0.200**	**1.133**
Divide by the smallest number	$\frac{0.161}{0.065}$	$\frac{0.065}{0.065}$	$\frac{0.200}{0.065}$	$\frac{1.133}{0.065}$
	2.47	**1**	**3.10**	**17.43**
	3	**1**	**3**	**17**
	$(CaO)_3$	**(Na_2O)**	**$(Al_2O_3)_3$**	**$(SiO_2)_{17}$**
	Ca_3O_3	**Na_2O_1**	**Al_6O_9**	**$Si_{12}O_{34}$**

Emprical formula of the Oxides	**$(Ca_3Na_2)O_4$**	**Al_6O_9**	**$Si_{17}O_{34}$**
Chemical formula of the mineral	**$(Ca_3Na_2)(Al_6Si_{17})O_{47}$**		
Mineral 1	**Plagioclase feldspar**		
Mineral 1 + SiO_2			
Mineral 2			

$(Ca_3Na_2)(Al_6Si_{17})O_{47}$ cannot be convertible using Zero polynomial of $(\Upsilon_{1-p}X_p)$ $(Q_{4-y}\mathcal{N}_y)\mathcal{W}_i$ because there is no polymerization in feldspar.

Therefore, using empirical formula, $(\Upsilon_{1-p}X_p)$ $(Q_{4-y}\mathcal{N}_y)O_8$ is **$(Ca_3Na_2)(Al_6Si_{17})O_{47}$**, as shown in Table 24 above. Then the true value of Plagioclase feldspar Mineral using Zero polynomial of $(\Upsilon_{1-p}X_p)$ $(Q_{4-y}\mathcal{N}_y)\mathcal{W}_i$ is **$(Ca_3Na_2)(Al_6Si_{17})O_{47}$**

The roots (λ_η) and (λ_Υ) of $(\Upsilon_{1-p}X_p)$ $(Q_{4-y}\mathcal{N}_y)O_8$ = **$(Ca_3Na_2)(Al_6Si_{17})O_{47}$** are {2, 2} and {4, 12} respectively and the solution = **$(Ca_3Na_2)(Al_6Si_{17})O_{47}$**

$(Ca_3Na_2)(Al_6Si_{17})O_{47}$ = 30% <u>Labradorite</u>

$An_{50}.Ab_{50}$ = 100%

100% (<u>Labradorite</u>) = 60%(<u>Anorthite</u>) + 40% (<u>Albite</u>) as shown in Table 20a, above.

Therefore, For 30%(<u>Labradorite</u>)

$(Fo(\frac{60x30}{100})\ Fa(\frac{40x30}{100})\% = An_{18}.Ab_{12}$

30% (<u>Labradorite</u>) = 18%(<u>Anorthite</u>) + 12% (<u>Albite</u>) of Miango basalt in **Miango Volcanic Field**

B: Classification of Felsic Minerals of <u>Miango basalt</u> in Miango Volcanic Field.

- **Feldspar classes** = 1[basic'**<u>Feldspar</u>**'] + [intermediate'**<u>Feldspar</u>**'] + i[acidic **<u>Feldspar</u>**].
- **Feldspar Minerals** = [basic'**<u>Anorthite</u>**'] + i[intermediate'**<u>Andesine</u>**'] + i[intermediate'**<u>Andesine</u>**'] +[acidic '**<u>Albite</u>**']

['**<u>Andsine</u>** '] = ['**<u>intermediate Feldspar</u>**']

['**<u>Miango basalt</u>** '] = **30%**['**<u>Andesine</u>**']

['**<u>Miango basalt</u>** '] = ['**<u>intermediate Feldspar</u>**']

4.4.4: Empirical formula and classifications for Ferrous/Ferric Oxides of Iron Ore of Miango basalt in Miango Volcanic Field using Zero Polynomial of ($\beta_{3-p}\alpha_p$)$(Z_0)_{\bar{\iota}}$

Table 4 above, represents the chemical compositions of **Ferrous/Ferric** Oxide of Miango basalt as analyzed using ICP-MS and can be mathematically analyzed using empirical formula below;

A: **Empirical Formula for the Ferrous/Ferric Oxides of Iron Ore of Miango basalt**

Therefore, the volume percent of Ferrous Oxides in Miango basalt are;

FeO = **12%** in Miango

TiO_2 = **2%** in Miango

12% + 2% = 14%

The Total volume percent of Ferrous Oxides in Miango basalt = 14%

FeO = **86%** in Iron Ore

TiO_2 = **14%** in Iron Ore

Therefore, the chemical compositions of Ferrous oxides in Iron ore can be expressed using empirical formula as shown Table 5 below.

Table 5: Empirical Formula for the Ferrous Oxides of Miango basalt

Oxides of the mineral	FeO	TiO_2
% composition of the Oxides	**86**	14
Molar mass of the Oxides	**68**	**78**

$\frac{\%composition}{Molar\ mass}$	$\frac{86}{68}$	$\frac{14}{78}$
Ratio of the Oxides	**1.20**	**0.20**
Divide by the smallest number	$\frac{1.20}{0.20}$	$\frac{0.20}{0.20}$
	5.2	**1**
	5	**1**
	$(FeO)_5$	**(TiO_2)**
	Fe_5O_5	**TiO_2**
Emprical formula of the Oxides	**$(Fe_5Ti)O_7$**	
Chemical formula of the mineral	**$(Fe_5Ti)O_7$**	
Mineral 1	**Ferrous Iron ore**	
Mineral 1 + TiO_2	**$(Fe_5Ti_2)O_9$**	
Mineral 2	**Ferric Iron ore**	

a. Conversion of **$(Fe_5Ti)O_7$** to true value of Iron ore Mineral using Zero polynomial of $Fe_{3-p}Ti_pO_4$

Therefore;

$Fe_{3-p}Ti_pO_4$ = **$(Fe_5Ti)O_7$**

$(Fe_2Ti)O_4 = (Fe_5Ti)O_8$

The roots (λ_η) of $Fe_{2-p}Ti_pO_4$ = **$(Fe_5Ti)O_8$** are 5 and 1 respectively and The solution = $(Fe_2Ti)O_4$

$Fe_{83}Ti_{17}$ = 100%

100% (<u>Ulvospinel)</u> = **83%(<u>Wustite)</u>** + **17%** (**<u>Rutile</u>**).

Therefore, For 7%(<u>Ulvospinel)</u>

$(Fo(\frac{83x7}{100})\ Fa(\frac{17x7}{100})\% = (FeO)_6\ (TiO_2)_1$

8% (<u>Ulvospinel)</u> = **7%(<u>Wustite)</u>** + **1%** (**<u>Rutile</u>**) **of Miango basalt** in **Miango Volcanic Field**

For ferric oxide;

$Fe_{2-p}Ti_pO_3$ = **$(Fe_5Ti_2)O_9$**

$(FeTi)O_3 = (Fe_{14}Ti_6)O_{30}$

$(Fe_{14}Ti_6)O_{30}$ = Ilmenite

The roots (λ_η) of $Fe_{2-p}Ti_pO_3$ = **$(Fe_5Ti_2)O_9$** are 14 and 6 respectively and

The solution = **$(Fe_{14}Ti_6)O_{30}$**

$(FeO)_{71}\ (TiO_2)_{29}$ = 100%

100% (<u>Ulvospinel)</u> = **71%(<u>Wustite)</u>** + **29%** (**<u>Rutile</u>**).

Therefore, For 7%(<u>Ilmenite)</u>

7% (<u>Ilmenite)</u> = **5%(<u>Wustite)</u>** + **2%** (**<u>Rutile</u>**) **of MIA** in **Miango Volcanic Field**

B: Classification of Iron Ore Minerals of <u>Miango basalt</u> in Miango Volcanic Field<u>.</u>

- **Iron Ore classes** = 1[basic'**<u>Iron Ore</u>**'] + [intermediate'**<u>Iron Ore</u>**'] + i[acidic **<u>Iron Ore</u>**].

- **Iron Ore Minerals** = [‘basic **Magnetite**‘] + i[Titano-manetite‘] + i[Titano-magnetite‘] +[acidic‘**Ulvospinel**’]
- **Iron Ore Minerals** = [‘basic **Haematite**‘] + i[Titano-manetite‘] + i[Titano-magnetite‘] +[acidic‘**Ilmenite**’]

[‘**Ulvospinel**‘] = [‘**acidic Iron Ore**‘]

[‘**Miango basalt**‘] = **7%** [‘**Ulvospinel**‘]

[‘**Miango basalt**‘] = [‘**acidic Iron Ore**‘]

Table 6: Mineralogical Compositions and Rock type of MIA in Miango Volcanic Field.

Minerals	**Olivine**	**Pyroxene**	**Feldspar**	**Iron ore**	**Silica**	**Others**
Chemical formula	**$Mg_{11}Fe_9$ $(Si_1O_4)_{10}$**	**$[(Ca_3Fe_4Mg_3)](Si_1O_3)_{10}$**	**$(Ca_3Na_2)(Al_6$ $Si_{17})$ O_{47}**	**$(Fe_2Ti$ $)$ (O_4)**	SiO_2	
Mineral type	Hortonolite	Ferro-augite	Labradorite	Ulvospinel	Quartz	
Percentage (%)	**35**	**10**	**30**	**25**	**0**	
Alkali content	$Na_2O + K_2O$ = **4.47%** $Na_2O + K_2O$ > **3%**					
Rock type	Alkaline Oivine Basalt, **Gabbro, ⇒ Olivine > 5%**					

(a) Numerical Observations of the **Rock of Miango basalt in Miango Volcanic Field:**

Numerically, the Mineralogical compositions of the Rock of **Miango basalt are,**

- **35% Hortonolite** of olivine,
- **10% Augite** of pyroxene,
- **30% Andesine** of plagioclase
- **25% Ulvospinel** of iron ore,
- 0% **Quartz.**

(b) Numerical analysis of the Miango basaltic Slide in Miango Volcanic Field as presented in Figures 1 and 2 below.

1. Porphyritic texture

30% porphyritic consisting:

- **Ferro-augite** (10%)
- **Hyalosiderite** (20%)

2. Groundmass

70% groundmass (neglecting vesicles) consisting

- **30% Labradorite** which is euhedral to subhedral shaped
- **15% Hortonolite** which is subhedral to anhedral

25% Ulvospinel, which exhibits anhedral elongate shape (**ilmenite**?)

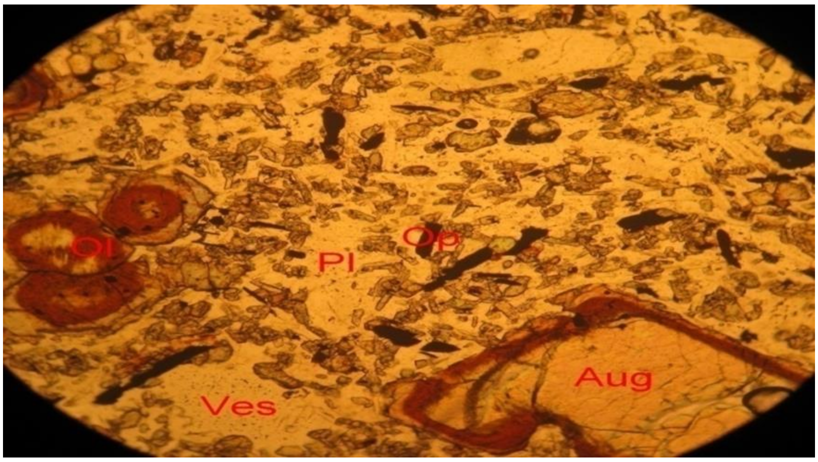


Figure 1: Photomicrograph of MIA, PPL showing the **35% of Hortonolite** and **10%** of **Ferro-augite** rounded by rims (**pigeonite**?), **30%** of **Andesine** and **25%** of **Ulvospinel**

Figure 2: Photomicrograph of MIA, XPL showing 35% of **Hortonolite** and **10%** of **Ferro-augite** rounded by rims (**pigeonite**?), **35%** of **Andesine** and **25%** of **Ulvospinel**

(c) Using Metrical Matrices:

1. Metrical Matrix for Mafic Olivine Minerals and Feldspars;

$$\begin{bmatrix} \mathrm{Ca}_1[Al_2\,Si_2]0_8 \\ [Mg_2]SiO_4 \end{bmatrix} + \begin{bmatrix} \mathrm{Na}_1[AlSi_3]0_8 \\ [Fe_2]SiO_4 \end{bmatrix} = \begin{bmatrix} (\mathrm{Ca}_3\mathrm{Na}_2)Al_6Si_{17}\,]0_{47} \\ [[Mg_9][Fe_{11}]\,[SiO_4]_{\,10} \end{bmatrix}$$

$$\begin{bmatrix} Anorthite \\ Forsterite \end{bmatrix} + \begin{bmatrix} Albite \\ Fayalite \end{bmatrix} = \begin{bmatrix} Labradorite \\ Hortonolite \end{bmatrix}$$

$$\begin{bmatrix} Labradorite \\ Hortonolite \end{bmatrix} = [\textbf{Alkali Olivine Basalt}]$$

2. Metrical Matrix for Augite Pyroxene Mineral and Feldspar;

$$\begin{bmatrix} \mathrm{Ca}_1[Al_2\,Si_2]0_8 \\ [\Upsilon_3]Mg_7]\,Si_{10}\,O_{30} \end{bmatrix} + \begin{bmatrix} \mathrm{Na}_1[AlSi_3]0_8 \\ [\Upsilon_3]Fe_7]\,Si_{10}\,O_{30} \end{bmatrix} = \begin{bmatrix} (\mathrm{Ca}_3\mathrm{Na}_2)(\mathcal{N}_6Q_{17}\,]0_{47} \\ [Y_3]Mg_3][Fe_4]\,[\boldsymbol{SiO_3}]_{\,20} \end{bmatrix}$$

$$\begin{bmatrix} Anorthite \\ magnesio-augite \end{bmatrix} + \begin{bmatrix} Albite \\ Ferro-augite \end{bmatrix} = \begin{bmatrix} Labradorite \\ Augite \end{bmatrix}$$

$$\begin{bmatrix} Labradorite \\ Hortonolite \end{bmatrix} + \begin{bmatrix} Labradorite \\ Ferro-ugite \end{bmatrix} = [\textbf{Alkali Olivine Basalt}]$$

With total alkali greater than **3%** (Na_2O + k_2O **>3%**), and the modal olivine greater **5%**, the expected basic rocks classification depending on their grain sizes, are **alkaline olivine gabbro**, **alkaline Olivine dolerite**, **alkaline Olivine norite or alkaline olivine basalt** as presented in Figure 3 below

Figure 3: Alkaline Olivine basalt at Miango Volcanic Field with total alkaline content greater than 3% and modal olivine greater than 5%.

5.0: SUMMARY, AND CONCLUSION

5.1: SUMMARY OF FINDINGS

In summary, the mathematical equations were used to calculate minerals in Basalts and as it outlines below:

1. Zo is the nucleation point of the recharged magma under thermodynamic condition and it is the silicate identity in the magma which is the building block of silicate minerals.
2. $f_n\,(Z_0) = [\beta + \propto]_{n+p} Z_0$ is the "formula" to calculate Mafic minerals from the magma under thermodynamic change
3. $(\Upsilon + \mathrm{X})_{m+p}\,(\mathcal{Q} + \mathcal{N})_{y+x}\mathcal{W}_x = (\Upsilon_{m-p}\mathrm{X}_p)(\mathcal{Q}_{x-y}\mathcal{N}_y)\mathcal{W}_i$ is the formula to calculate for complex minerals under thermodynamic change, where $(\Upsilon + \mathrm{X})_{m+p}$ is the lattice of ions of different sizes and charges and $(\mathcal{Q} + \mathcal{N})_{y+x}\mathcal{W}_x$ is another lattice of ions of different sizes and charges in the same mineral to maintain electrical neutrality in the minerals
4. Applying these formulae from number 1 and 2, it results to matrices to produce the resultant rocks as given bellow;

- If P > A, then the intermediate rock is the Andesite
  [Basalt] + [Dacite] = Andesite
- P < A, then the intermediate rock is the trachyte
  [Basalt] + [Rhyolite] = Trachyte
- If P = A, then the intermediate rock is the Hybrid Monzonite

[Basalt] + [Rhyolite] = Hybrid Monzonite

5. Using petrographic microscope, minerals observed during studies of Kassa basalts are mathematically represented by
   - Matrix Method: the minerals that set in matrix include, olivine, pyroxene and plagioclase
   - Set Notation: they are the elements that form set when partitioned in Kassa Basalts. They include [Cr, Zr, Ni, Mn, Sr, Va and Ba]

6. The mathematical analysis after extensive geochemical analysis and petrographic studies indicates that Kassa Basalts are

- Olivine Basalt: Olivine > 5%,
  : Na_2O < 3%
- Alkali Olivine Basalt: Olivine > 5%,
  : Na_2O >3%
- Tholeiite Basalt type : Olivine > 5%,
  : Na_2O >3%

5.2 CONCLUSION

Using Bowen's and Goldschmidt concepts according Achuenu and others (2025), the formula $f_n\,(Z_0) = [\beta + \propto]_{n+p} Z_0$ for mafic minerals and $(\Upsilon + \mathrm{X}\,)_{m+p}(\beta + \alpha)_{n+p}$ $(\mathcal{Q} + \mathcal{N})_{y+p}\,\mathcal{W}_i = (\Upsilon_{m-p}\mathrm{X}_p)\,(\beta_{n-p}\alpha_p)(\mathcal{Q}_{y-p}\mathcal{N}_p)\mathcal{W}_i)$ for felsic and complex minerals were successfully used in this research to calculate the numerical values of minerals in Kassa basalt, particularly, For MIA.

From the Mathematical modeling, it is also concluded, that the examinations of sampled rocks collected from Miango Volcanic Basalts, under thin section, chemical analysis using **ICPMS,** and mathematical computation indicate, that minerals observed and chemical composition analyzed, fall within gabbro clan. The gabbro clan includes basalt, dolerite, norite, scoria and gabbro. The minerals observed in these rocks under thin section are restricted to Gabbro clan and they are mainly basic, because of its instability in the presence of free silica. It is on this note, conclusion was made that, mathematically Miango volcanic Basalts particularly for average samples of **Miango basalt** as shown in Table 1 above, are characteristics of rocks of Gabbro clan and the rock type for **Miango basalt** is **olivine, alkali basalt magma type** as shown in Table 1 above.

Data Availability Statement

The raw data supporting the conclusions of this article are available from the corresponding author upon reasonable request.

Conflict of Interest

The author declares no conflict of interest.

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