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**13**

# SPATIAL DISTRIBUTION OF VOLCANOES IN NORTHERN NIGERIA: A GIS APPROACH

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**Abstract:** *The aim of the mapping exercise is to identify the volcanic signatures within the Nigerian land –mass, investigate their activity and predict through dating possible re-occurrence in future as well as determining hazard vulnerabilities. Our investigations identified sixteen (16) volcanic cones outcrop in the Jos Plateau and twenty-eight (28) of such in the Biu Plateau. The study affirms that volcanic cones of Jos Plateau are composed essentially of volcanic ash, lappilli, bombs, tuff agglomerates, basalts and scoria. Most of them occur as single cinder cones (like at Miango, Passakai, Wushik, Kerang Swan junction etc.) but rarely as clusters of two or more (for example, Jiblik, Kassa, Kerang twin volcanoes, Pidong among others). The study also affirms that Biu Plateau are constituted by a large volume of volcanic ash and pyroclastic materials (for example, at Gwamya, Tilla Crater Lake, Gadam, Batadeka, Bwatai, Kwatla volcanoes among others) suggesting that there was a tremendous spewing of ash and gases into the atmosphere prior to the violent eruptions and in-between the eruptions. If any of these volcanoes erupt today with the same intensity and volume presumed the whole state and the neighbouring states would be thrown into chaos. GIS analytical techniques like overlying and buffering showed clearly that the population of people living around these volcanoes totals about 1.5 million people. This means that about half the population of Plateau State is potentially at risk of volcanic eruption. The study concludes that the distribution of volcanoes varies over space on both Biu and Jos Plateau. Hence, public awareness of their hazard potentials and encouragement of increased public participation, as well as government and professional intervention in proper management and monitoring of these volcanoes should be encouraged.*

**Key words:** Mapping; Volcano; Vulnerabilities; Nigeria; GIS

## Introduction

The mapping of patterns in the spatial distribution of features has been of great significance in virtually all fields. The primary aim in the mapping process is to bring out hidden relationships among variables. This becomes important because geographical distribution of spatial feature reflects the social and environmental conditions that affect risk, susceptibility, social interaction and behaviors that facilitates occurrence (Oluwafemi *et. al;* 2013). According to Geology Dictionary, volcano is a vent or outlet which transfers magma or molten rock from the earth crust to the Earth's surface. Volcano can be categorized into active and dormant volcano. It is widely known that volcanoes are named from Vulcan the Roman god of fire (Wright 1979). According to Lar and Tsalha (2005), volcanism is the eruption of molten rock (magma) onto the surface of the Earth crust. Volcanic eruptions and their effects are amongst the earth's most destructive natural events. Empirical research suggested that about 600 volcanoes have erupted worldwide in the past 200 years (Turner 1978). The challenge of volcanism has been an issue of global concern, especially in Asia and sub- Sahara Africa. Approximately 50 volcanoes erupt around the world. Apart from the

danger pose by volcanic eruptions, they provide some of the world's most breathtaking scenery.

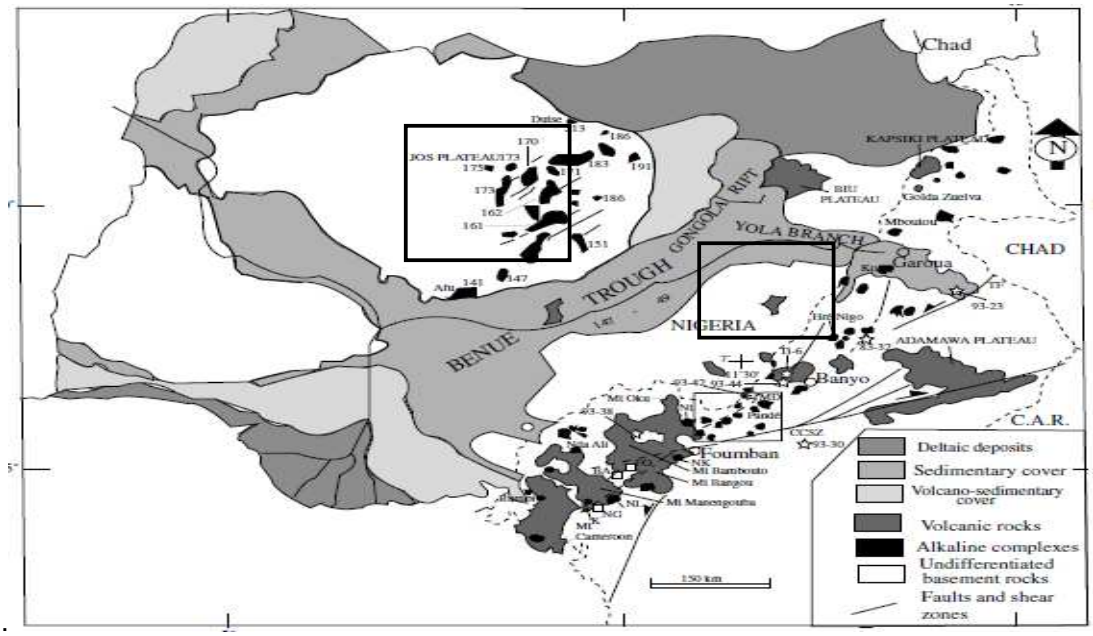
According to Lar and Tsalha (2005) volcanism occurs when earth crust loses its internal heat; it can be formed where rock near the surface becomes hot enough to melt. On Earth, this often happens in association with plate boundaries where two plates move apart, such as at mid-ocean volcanic ridges, material from Earth's interior slowly rises up, melts when it reaches lower pressures, and fills in the gap (Ewert et al; 2005). Although, most volcanic activity takes place at plate boundaries, volcanism also can occur within the plate interiors at hotspots just like in the case of Nigeria (Akpan and Yakubu, 2010). Volcanic hotspots are thought to be from large plumes of extremely hot material rising from deep in Earth's interior. The hot material rises slowly, eventually melting as it reaches lower pressures near Earth's surface. When the material erupts it forms massive lava flows of fine-grained dark volcanic rock basalt (Grant *et al;* 1972). The broad, gentle shield volcanoes of Hawai'i come from a hotspot (Lar and Sadiu 2004). The term vulnerability referred to people and property threatened in regions of hazardous events (Ewert *et al*. 2005). The concept of vulnerability needs to incorporate the differential susceptibility and aspects of impacts to aid in risk mitigation (Hill and Cutter, 2001). Studies have shown that lava flows have buried communities; explosive eruptions have destroyed forests and killed people, debris avalanches and mudflows have clogged major river ways, damaged bridges, and swept bystanders to their deaths; noxious gas emissions have caused lung ailments; ash clouds have caused damage to aircraft and disrupted the lives of thousands of people (Hill and Cutter, 2001; Turner 1978). In Nigeria, empirical studies have shown that quite a number of dormant volcanoes are visible all over the Jos and Biu Plateau. However, these volcanoes represent previous volcanic eruption sites and are therefore potential future eruption sites. Thus, the possibility of a volcanic eruption taking place in Nigeria cannot be completely ruled out (Lar and Sadiu 2004). This is further more affirmed by the several incidences of volcanic eruptions along the nearby Cameroon volcanic line (in 1909, 1922, 1959 and 1982) at the north eastern extremity of Nigeria. In most cases, the impact of such eruptions, such as minor tremors, flooding along river channels and sudden temperature rise etc. have been experienced in the neighbouring Taraba, Adamawa and Benue States of Nigeria. The potential for such threats to the nation's population, property, and infrastructure is significant and there is a need to map volcanic eruptive behaviours using geospatial techniques to help mitigate effects of these forces of nature (Ewert *et. al;* .2005). Hence, this study analyses the spatial distribution of volcanic eruption on both Jos and Biu Plateau, using geospatial techniques with a view of aiding the policy makers in providing a framework for the control of natural hazards and improves natural hazard management.

**Study Area**

Nigeria, The most populous country in Africa and the tenth largest country by population in the world, is located at the eastern terminus of the bulge of West Africa. The geographical location of the Federal Republic of Nigeria is between latitude 4˚N to 14˚N; and longitude 3˚E to 15˚E (Figure .1). It has a land extent of about 923,769 km$^2$; a north-south length of about 1,450 km and a west-east breadth of about 800 km. It is a country with diverse biophysical characteristics, ethnic nationalities, agro-ecological zones and socio-economy. Abuja is the capital and Lagos is the most populous city and main commercial centre. The country has 36 states with 774 Local Government Areas. The Jos Plateau is located in the central part of Nigeria while Biu Plateau is located in a highland area in North-eastern part of Nigeria

containing many recently extinct volcanoes. It is located between Longitude 12° 00´E to 12°30´E and Latitude. 10° 19´ N to 11° 00´ N. It covers about 5,200 km (2,000 sq. km) and has an average elevation of 700 m (2,300 ft.). The Jos Plateau lies between the Upper Benue Basin to the south and the Chad Basin to the north. The plateau covers an area of about 7,800 sq. km (about 3,000 sq. mi) and lies at a general altitude of about 1,300 m (about 4,300 ft.). It is surrounded by high plains with elevations of between 600 and 900 m (2,000 and 3,000 ft.) and consists mainly of deeply eroded remnant volcanic rock, mostly granites (Lar, and Tsalha, 2005). The Tertiary volcanic activity was concentrated on the Jos Plateau, the Benue trough and along the Northeast to Southwest Cameroon Line (Figure 1). Most of the main volcanic regions are characterized by basement uplift and these also include the Bameda Highlands, the Mambila Plateau and the Adamawa Plateau (Turner, 1997). Similarly, the Basement in the Biu Plateau marks a structural culmination between the Benue and Chad basins. The Cameroun Volcanic Line comprises of the Gulf of Guinea, Island of Anoobon, Sao Tome and Principe and Fernando Po and also the Cameroun Mountains, Bameda Highlands comprising of Manemgomba, Oku, and the Mambila Plateau. South east of the Cameroon line, the line splits into two branches, one runs into northern Nigeria and includes the Biu Plateau, while the other runs eastwards through the Ngoude Plateau of eastern Cameroun. On the uplifted Jos Plateau, volcanic rocks are represented by basaltic lava flows and volcanic cones (Mackay *et. al;* 1949). Here these relics volcanic rocks are classified into two (namely Older and Newer basalts) based on their differences in age of emplacement, mode of occurrence, mineralogy and texture (Lar and Tsalha, 2004).

Fig.1: Map of Nigeria Showing the study area




## Methodology

The research methodology was discussed under the following; reconnaissance survey, data sources and acquisition, data collection procedure, data preparation and analytical techniques used in the study.

## Field Investigation

### Reconnaissance Survey

A reconnaissance survey and actual fieldwork of the study area was undertaken was conducted. The study was conducted during three field seasons which included a desk study, compilation of existing data (topographical, geological, population, satellite and soil type data) acquired from relevant agencies, meetings and discussions with governmental organizations at Federal and State level. During the actual field survey, information about locality of the volcano, geographic coordinate and type of volcano, diameter of crater, elevation and materials deposited were also noted.

### Data Sources and Acquisition

Both primary and secondary data were used in this research. The primary data involved the use of Handheld Global Positioning System to obtain the geographic coordinates of both active and dormant volcanoes on both Jos and Biu plateau. The Ground Control Points (GCPs) were used in the map georeferencing within ArcGIS environment. The methodology adopted from this study includes desk study and field investigation. The secondary data includes compilation of existing data (topographical, geological, population, satellite and soil type data) acquired from relevant agencies which was used as themes in the ArcGIS 9.3 for further analysis.

### Geospatial Analysis

The georeferenced map was exported to ArcGIS 9.3 environment. Thereafter, relevant layers (state boundary, settlement, and volcano) were digitized and the various attribute were populated. These positional and attribute data were overlaid as themes with their shape files in ArcGIS. Three GIS spatial analysis were used to analyse phenomena of interest. The study also developed a Geographical Information System (GIS) database and mapped volcanoes in Nigeria using ArcGIS 9.3. The buffering analysis was performed on each volcano within the study area. Figure 2 shows the buffering analysis with 50km radius around the volcanoes. The settlements within the buffered zones of were mapped and identified with their respective population. The buffering analysis was also performed on the volcanoes on Biu plateau with 60 km radius. The settlements within the buffered zones were also mapped and identified with their population figures.

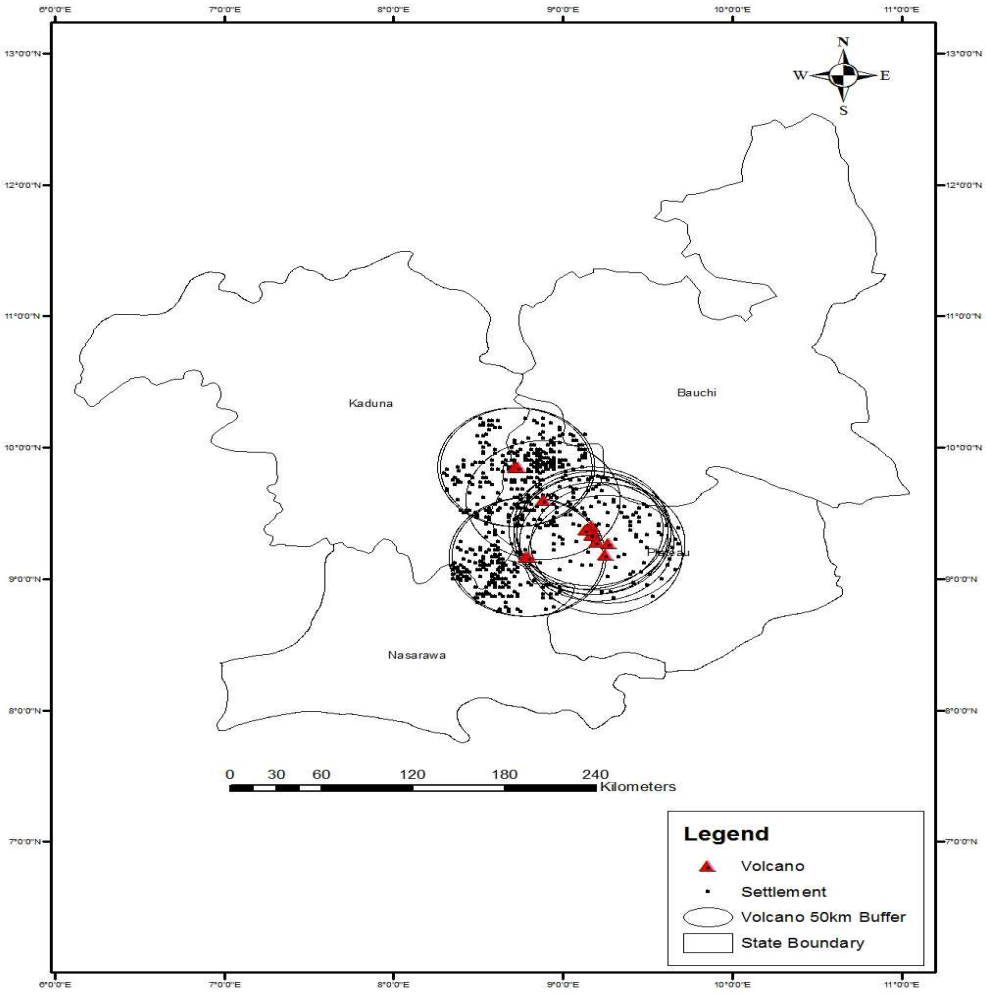
## Results and discussion

### Jos Plateau

Our investigations show that about 16 volcanic cones outcrop of the Jos Plateau. They are aligned mainly in NNE-SSW directions. The volcanic cones are composed essentially of volcanic ash, lappilli, bombs, tuff agglomerates, basalts and scoria (Table 1). Most of them occur as single cinder cones (like at Miango, Passakai, Wushik, Kerang) but rarely as clusters of two or more (for example, Jiblik, Kassa, Kerang twin volcanoes, Pidong etc.). These individual cones reflect the number of major successive eruptions. In places, where single cones occur, one would observe a series of minor hills aligned in the direction of the collapsed flank. This is very visible with some volcanic cones within the Sura line (e.g. Nyeis and Kerang volcanoes). There are clear indications that in each of the alignments, the volcanoes at the northern end are the most highly weathered relative to those towards the southern end. For example, in the Miango-Vom-Kassa line, the Miango volcanoes at the northern end are relatively weathered compared to those of the Kassa hills. So also within the Kassa clusters of volcanoes (which extend for about 3 km) the intensity of weathering

tends to decrease from the north to the south. This same scenario is also observed within the Sura Volcanic line, where the presence of the relatively fresh basaltic/pyroclastic constituent materials at Pidong suggests it is the youngest within the line. The same is true of the GU Volcanic line.

Figure 2: Vulnerability Map of Volcanoes on Jos Plateau




Thus, there is a correlation between the positions of these volcanoes and their ages. The oldest formed volcanoes in a given alignment are represented by those in the northern end and are progressively younger towards the southern end. This relationship is akin to that presented by the Younger Granite ring complexes, which have been dated and gave ages decreasing progressively from North to South. The alignment of these volcanoes possibly marks the relative movement of the African plate over the lower mantle “hot spot” which is presently beneath the Atlantic Ocean (Baudin, 1991). The abrupt change in alignment within these two volcanic provinces studied is a reflection of this relative movement at some time during the Tertiary- Quaternary times. The cluster of these volcanoes and the relatively close distance between one and another for example Kerang I, II, and III suggest a relatively small interval of time between two or more major eruptions. Also, the relatively large size of some of these volcanoes (Miango, Kassa, Jiblik, Kerang etc.) suggest that quite a large volume of

magma was extruded covering quite a large landmass (valleys and low-lying plains) as lava flows.

Table 1: The Volcanoes on the Jos Plateau

| Name/Locality | Estimated population of people at risk | Materials Deposited |
|---|---|---|
| Miango volcano I | For 1 & 2 250,000 | Scoraceous basalt/pyoclastics |
| Miango volcano II | | ‘’ |
| Kassa volcanoes | 100,000 | Olivine basalt, scoria, tuff, breccia/volcanic bomb |
| Sha 1 | 20,000 | Pyroclastics (granite fragments/lava) |
| Sha 2 | 10,000 | Weathered basaltic materials Capped by Iron concretions |
| Passakai | 10,000 | Lateritized. |
| Wushik (Lakas) volcano | 10,500 | Scoria/pyroclastics |
| Kogul (Nyeis) volcano | 80,000 | Scoria/pyroclastics |
| Kerang I | I to IV put together 200,000 | Scoria/basaltic rocks with large phenocryts of olivine, garnet and pyroxene. |
| Kerang II | | Scoria/basaltic rocks with large phenocryts of olivine, garnet and pyroxene. |
| Kerang III volcano (Swan junction) | | Scoria/pyroclastics. |
| Kerang iv | | Pulverised Basement and lava. |
| Pidong volcano | 50,000 | Scoria/pyroclastics. |
| Jiblik volcano | 100,000 | Scoraceous basalt +garnet/pyroclastics |
| Kagu volcano | 50,000 | Scoraceous basalt/pyroclastics |
| Katul volcano | 5000 | Scoraceous basalt/pyroclastics |

**Biu Plateau**

The volcanoes of the Biu Plateau present similar characteristics as those of the Jos Plateau (Table 2). The volcanoes form near linear alignments from the north to the south and extend right through the low-lying Basement complex into the Sedimentary formations of the Benue valley (Garkida-Gombi-Song areas in Adamawa State). The volcanoes have very large craters of greater than 1 km, (referred to as caldera). The volcanoes extruded directly the basement rocks and therefore are of lower altitude above sea level when compared to those of the Jos Plateau, which extruded the already high-level Younger Granite bodies. Unlike the clusters of volcanic cones seen on the Jos Plateau (Kassa and Pidong volcanoes), those of the Biu Plateau are simple but very large in diameter (Caldera). The large size of most of these volcanoes coupled with their number and the superficial area covered, suggests that quite a large volume of magma, volcanic ash, dust and gases erupted. Also, unlike the volcanoes of the Jos Plateau, those of the Biu Plateau are constituted by a large volume of volcanic ash and pyroclastic materials (for example, at Gwamya, Tilla Crater Lake, Gadam, Batadeka, Bwatai, Kwatla volcanoes etc) suggesting that there was a tremendous spewing of ash and gases into the atmosphere prior to the violent eruptions and in-between the eruptions. Also, the highly muddy and slippery nature of the environment during the rainy season attests to this. Certain basaltic rocks of the Biu Plateau have given

ages as young as 0.8Ma (Grant ***et. al.,*** 1972). A younger age of 0.5 Ma has also been reported for some Newer Basalts of the Jos Plateau (Burke and Durotoye, 1974). These ages compare to ages of certain volcanoes considered extinct but have roared back to life. This will include in addition large populations living at the neighbouring Kaduna, Nassarawa, Gombe, Adamawa, and Taraba states.

Table 2: The Volcanoes on the Biu Plateau

| **Name/Locality** | **Estimated population of people at risk** | **Materials Deposited** |
|---|---|---|
| TASHA VILLAGE | 5000 | Massive basaltic rocks |
| AFTER TASHA VILLAGE | 5000 | Massive/Vesicular Basaltic rocks |
| TAGWAYE (TWIN) VOLCANOES (In Kwaya Kusar LGA of Borno State) | 15,000 | Olivine basalts/ Agglomerates. |
| GADAM VOLCANO (Kwayar Kusar LGA, Borno State) | 30,000 | Olivine Basalt |
| Location 5 | Inhabited | Basaltic boulders/Agglomerates/tuff |
| Location 6 | Inhabited | Vesicular Basaltic boulders/Agglomerates/tuff |
| TUM | 10,000 | Scoraceous basalt with olivine/zeolite/Columnar basalt. |
| Wakama (a) (BCG Village) | 2,500 | Scoraceous basalt |
| Wakama (b) | 2,500 | Scoraceous basalt |
| Gwamya Volcano | 6,000 | Scoraceous basalt/pyroclastic pile |
| Tilla Volcanic Hill | 2,500 | Scoraceous basalt/pyroclastic pile |
| Tilla Crater Lake | 10,000 | Scoraceous basalt/pyroclastic pile |
| VERSU Volcano | 3,000 | Olivine basalt |
| DRAGNA Volcano | 5,000 | Weathered scoraceous basa Basalt |
| MARAMA Volcano | 150,000 | Scoraceous basalt/pyroclastics |
| GWARAM VOLCANIC HILL | 8,000 | Boulders of scoraceous basalt |
| BATADEKA I VOLCANIC HILL | 3,000 | Weathered Scoraceous basalt |
| BATADEKA II VOLCANIC HILL | 3,000 | Weathered Scoraceous basalt |
| KWATLA CRATER LAKE | Inhabited | Weathered scoraceous basalt |
| MALDAU | Inhabited | |
| BURATAI VOLCANIC HILL | 5,000 | Weathered scoraceous basalt/ pyroclastics |
| KONA UKU VOLCANIC HILLS | 10,000 | Weathered scoraceous basalt/ pyroclastics |
| DUTSEN KURA (BOGUR) VOLCANIC HILL | 5,000 | Weathered scoraceous basalt/ pyroclastics |
| KUKUWA (Gabai LGA Yobe State) | 5,000 | Columnar basalt |
| Kukuwa II | 5,000 | Columnar basalt |
| KURARA VOLCANIC HILL(Garkida junct Ad State) | 50,000 | Weathered scoraceous basalt/pyroclastics |
| SONG (Song-Gombi Road) | 50,000 | Weathered scoraceous basalt/pyroclastics |
| SONG (Hawul Mountains) | 10,000 | Weathered scoraceous basalt/pyroclastics |

**Conclusion and Recommendations**

From the investigations, many indices contributed to the high probability of some of these volcanoes roaring to life such as the Tila and the Pidong volcano. It is worthy of note also that none of these volcanoes have erupted during our time. There are no records to show that an eruption did occur at a given time in our history. However, the presence of these

volcanic edifices alone is enough clues to the likelihood of an eruption. From this study it is estimated that about half the total population of Plateau and Borno states are at risk. The spatial analysis of the volcanoes on both Jos and Biu Plateau region helped identify where future hazard mitigation projects should be focused. The result indicated that it is important to focus on minimizing impacts from the hazards in the following order: pyroclastic flow areas, debris avalanches, tephra fallout areas and lahars. The study reveals that sixteen (16) volcanic cones outcrop in the Jos Plateau and twenty-eight (28) of such in the Biu Plateau. The study concludes that the distribution of volcanoes varies over space on both Biu and Jos Plateau. Hence, public awareness of their hazard potentials and encouragement of increased public participation, as well as government and professional intervention in proper management and monitoring of these volcanoes should be encouraged.

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