# Seismic Activity in Nigeria.

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## ABSTRACT

This paper presents an account of the earthquake activities in Nigeria. It includes a discussion of the possible origin and mechanism of the earthquakes. These developments in the nation's geological history bring to question the age long belief that Nigeria is seismically safe. It is difficult to overlook the incidence of earth tremors in the country because recurring tremors could be a build-up to a major earthquake.

(Keywords: earthquake, tremors, geological history, seismic activity)

## INTRODUCTION

This paper presents a discussion of the earthquake activities in Nigeria (Figure 1). This information is non-instrumental. It includes a discussion of the possible origin and mechanism of the earthquakes. These developments in the nation's geological history bring to question the age long belief that Nigeria is seismically safe. It is difficult to overlook the incidence of earth tremors in the country because recurring tremors could be a build-up to a major earthquake.

Earthquakes result from stresses which accumulate within the outer 700 km shell of the earth. The origin of these stresses are still obscure, both as to the source of energy and as to the mechanism by which this energy is converted to strain energy. The energy source is generally assumed to be of thermal origin (radioactivity, cooling, etc.), although other sources such as gravitational forces may also be active. The mechanisms which have been suggested for transferring thermal energy into mechanical energy or elastic strain are convection currents, change of phase or state, diffusion processes, expansion, or contraction.

Gravitational return to equilibrium from disturbance produced in the past may also play a role. However, these mechanisms appear to be generally inadequate to explain all known observations, so that other as yet unknown sources may also be active.

## RECENT SEISMIC ACTIVITIES

On June 27, 1990, an earth tremor occurred in Ibadan, West Africa's largest city, in Oyo State (Figure 1 ). The nation lacks seismic equipment to measure tremors or to monitor movement in the Earth's crust. An unscientific method of measuring the intensity of the quake is to have the testimony of eye- (or sense-) witnesses who were at or near the area of greatest intensity. For it is they who can describe the effects on the infrastructure. In comparing numerous accounts from witnesses of the same events, one can notice that there is a general agreement on major and minor details of the earthquake. Buildings vibrated to their foundation, braking louver blades of windows and stopping clocks. When whole buildings go into sudden violent vibrations, washing basins and plates tumbled, spilling their contents. The tremor sent people into the streets, though no one was killed.

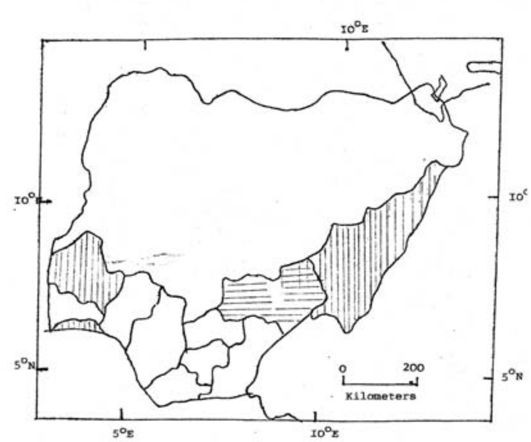


**Figure 1:** Map of Nigeria. Areas with Seismic Activity are Shaded.

Residents of Oluyole Estate Extensions, Apata, Odoowa and Felele, an area covering about 16 kilometers radius, experienced the highest vibration. If the quake had lasted more than 10 seconds, it could have resulted in the collapse of some houses. In fact, in a country where buildings are as collapsible as bubbles, repeated tremors could have a devastating effect. While some people impute supernatural cause to these quakes, others regard them as some sort of penance imposed for group sins. The effect of this tremor would suggest a micro-quake of magnitude m 3-4.

An earthquake was first reported in Ibadan in 1949. On July 28, 1984, another tremor occurred in Ibadan but many people did not take it seriously. Some people though it was thunder or the sound of a heavy vehicle passing near their residence. Unlike the 1990 event, the tremor left no casualties or significant damage to property. However, five days after the 1984 tremor, in Ibadan, Ijebu-Ode and Abeokuta, (Figure 1 ), two main settlements 68 km to the southeast and 77 km to the southwest, respectively, were hit by a more ferocious tremor that left cracks in buildings. The tremor which lasted for only two seconds affected Sobo, Porogun, Oliworo quarters, the Ondo-Benin road, and neighboring villages. Thus the Ijebu-Ode tremor spread very far.

The local geology of the region around Ibadan, which is the main area of interest, is underlain by rocks belonging to the migmatite-gnesiss-quatrzite complex which constitutes the essential part of the Precambrian basement complex of Nigeria. The migmatite-gneissess are heterogeneous rock made up of several distinct petrologic units (Rahaman and Ocan, 1978; Rahaman, Olarewaju, Ocan and Oshin, 1983). The two main petrologic units in the area are grey gneiss and the granite gneiss. The granite gneiss which forms the hills in addition to a few level outcrops is intrusive into the grey gneiss. All the rocks have undergone strong deformation and as a result show microfolds, and microfaults and linear fabrics.

The first earth tremors in Nigeria were in Warri (Delta part of Nigeria ) in 1923. It also occurred in Ohafia (eastern part of Nigeria) in 1933. On December 8, 1984, a tremor was reported in Yola, Gongola State (Figure 1). In April 1990, there were reports of strange shaking of the earth in Jere town, Kaduna State (Figure 1). Some cracks, suspected to have been caused by volcanic eruptions, were noticed in September 1988 in Osererun hills in Gombe council area of Gongola State threatening about 10,000 inhabitants. Two hectares of farm land and many animals were lost. In April 1988, panic gripped the inhabitants of Amauzu Ede-Obela in Edema council area of Anambra State where about 12 km of land had cracked. Houses built with zinc also had cracks. There are reports of annual tremors in some areas of Rivers State, especially during the month of April. These incidents have aggravated the fear of a possible earthquake across the nation.

The relative movement of plates give rise to earthquakes. The slip on the fault generates the earthquakes, according to plate tectonics. However, it is widely held that the African plate has not moved in the past 200 years. Stratigraphic evidence and K/Ar dates from widely separately areas on the African plate indicates a roughly simultaneous upsurge in volcanic activity about 25 m.y. ago (Burke and Wilson, 1972). If this volcanism was generated over plumes and the African plate has moved laterally over them during the past 25 m.y., then the volcanoes should form parallel lines across Africa. If the motion averaged 1 cm/yr, the lines of volcanoes would be 250 km long and all would become younger in the same direction. Although African Neogene volcanoes are commonly arranged in lines the lines are not parallel and there is no evidence of consistent age variations from one end to another. This pattern of volcanism is consistent with the hypothesis that the African plate halted and has been virtually at rest for the past 25 m.y. with each Neogene volcanic area overlying a different plume (Burke and Wilson, 1972).

The affected areas do not lie on any plate boundaries. What then could be the possible origin of these earth tremors in these areas? We want to attempt plausible causes for these earth tremors. One thing is certain, that is, the earth tremors that have occurred in Nigeria have occurred in the same area. Thus, these earthquakes do not occur randomly either in time or in space on the surface of the earth. There are distinct earthquake belts in Nigeria. Then there must be some interesting features in these particular areas. Certainly, the earthquakes in the different parts of Nigeria can not be ascribed to the same cause. The seismically active zones are (Figure 1).

1) South-west zone stretching from the Ijebu areas to the Ibadan areas.
2) The Cross Rivers Basin,
3) Gongola Trough,
4) Benue Valley.

In the southern part of the country such as Warri and Rivers State (Figure 1), the earthquakes may be due to sediments. In areas where the earth is overloaded, the plate is upset. This could precipitate earth movement because the application of stress to a rock mass having a structural weakness produces a fracture. Once a fracture has occurred, movements will continue on it. However, sedimentation alone is generally inadequate to induce earthquakes. This is because the large sediment loads have generally been in place long enough that the stress had relaxed.

Warri and Rivers State are in the Niger Delta. The Niger Delta is underlain by an RRR (Ridge-Ridge-Ridge) triple junction (Burke et al., 1971) and lies on an oceanic crust (Hospers, 1971).

Reyment (1969) published a map showing an estimate of the former position of the edge of the South American continent under the Niger Delta based on the distribution of marine Upper Cretaceous rocks. The northern limit of growth faults (Short and Stauble, 1967; Merki, 1970) in the Niger Delta roughly coincides with the same line, that is, the Cretaceous margin of South America and this seems consistent with the general observation that the deltas are pushing into waters of oceanic depths and which have been suggested to represent the results of a short-lived subduction episode (Burke et al., 1971) which could trigger earth tremors in these areas.

Cities such as Warri and Rivers State which are located on water-logged unconsolidated sediments, that is, loose gravel, sand, dirt, and clay and near major faults are more vulnerable to earthquake damage than those that are not. Unconsolidated sediments are at much greater risk for seismic shaking than rock.

Some areas of the country are sinking because of the rate at which the nation's underground water resources are being tapped. Thousands of boreholes in Lagos State, for example, are from a single source, the Abeokuta rocks in Ogun State. An earth tremor occurred in Abeokuta in 1986. The water collects underground and literally floats the whole city. Groundwater behavior is now acknowledged to be an important factor in earthquake prediction especially since Nur proposed a dilatancy-diffusion hypothesis of precursor behavior (Nur, 1972). Many reports concerning groundwater behavior accompanying earthquakes have been recorded (Shimamura, 1980; Shimamura and Watenbe, 1981; Shimamura et al., 1985; Wakita, 1981). However, much remains unknown about the role of groundwater in earthquake generation.

Gravity and structural geology of the Benue valley indicate a combined effect of a zone of intrusion, a thin crust and possibly a shallow basement (Ajakaiye and Burke, 1972). This conclusion is consistent with the hypothesis that a spreading ridge underlay the southwestern part of the Benue trough in part of Cretaceous times with closure of the embryo Benue ocean at the time of a major Santonian folding episode (Burke et al., 1971). On this hypothesis the thick sedimentary sequences mark the suture along which continental crust has rejoined after the short-lived spreading episode. Rex, et al. (1971), have suggested that the Neogene volcanism of the Benue trough with its low $^{87}Sr/^{86}Sr$ ratios may have been localized along this suture. This localized volcanism may be responsible for the seismic activities in the Benue Valley.

The reactivation of pre-existing faults or weak zones has been observed in the ocean and inland (Wetmilla and Forsyth, 1978) and this process is proposed for the Ibadan area. This intra-plate area constitutes a localized weakness zone in the crust. The cause of this weakness is unknown. It is possible that the stressed rock becomes weakened by water corrosion and the pushing apart of the forces of the fault by abnormally high pressures. There is the possibility regarding the concentration of strain in relatively narrow strain zones along the faults. Thus, the major portions of the blocks between faults are relatively unstrained and so act principally as stress transmitting members of narrow strain zones at their margins, where the strain is accumulated for intermittent release in earthquakes. However, we do not know the nature of the forces which produce the stresses. Perhaps, the forces originate from within the whole block masses as body forces and are applied horizontally from outside the affected region, or are generated by coupling to many structures below. We do not know the depth to which the faults and their strain zones extend.

Kennedy (1965) recognized that Cretaceous and Tertiary marine sediments were confined to the reactivated areas in the Pan African orogency around the West African craton. Burke and Dewey (1971) and Dewey and Burke (1973) in attempting to apply unformitarian principles to the Pan African events, emphasized that these terraces resembled, in their vast areal extent, the kind of orogenic environment presently resulting from continental collision in the Himalaya and Tibet. They suggested, therefore, that Pan African reactivation might have resulted from continental collision

## DISCUSSION

The Atlantic-type continental margin of Nigeria was generally regarded as aseismic until these tremors. This suggests that the crust in the west African portion of the African plate may not be stable. Before the acceptance of plate displacement, it seemed appropriate to relate surface structures directly to those of the underlying asthenosphere but this is no longer realistic unless a plate can be shown to be temporarily at rest.

The basin and swell structure which are peculiar to Africa are linked to the rift valley formation (Krenkel, 1957). Burke and Whiteman (1970) have postulated a genetic sequence, discernible in Africa, from uplift, through rifting and triple junction formation to continental separation. They suggested that these peculiarities of Neogene African structure (in no other continent are they so prominent) may be a consequence of the standstill of the African plate over asthenosphere.

The Nigerian continental shelf lies between longitude $30^0$ west and 80. $40^0$ east and latitude $60.20^0$ N and $40.20^0$ N. It evolved about 180 million years ago when Africa began to separate from south America (Junner, 1941). The mantle in the ridges is jutting to the surface, thereby causing fractures along the ridge. Some of these fractures have been found to cut into the African continent, although the precise location in West Africa has not been determined. Rock movement along the fractures are rampant and so builds up tension and force which at a point snaps or yields to cause vibration to the landmass in what is experienced as tremors. However, no evident oceanic fracture seems to be related to this epicentral region. The shelf does not extend that far from the coast.

As further evidence that the west African nation is unstable, earthquakes were reported in Accra, Ghana, west of Nigeria. Several seismic events have occurred in Accra extending along the Akwapin faults to the Volta River (Burke, 1969). Ghana does not belong to any of the known mobile zones, rather it belongs to a stable area, the craton. However, the history of earthquakes in Ghana suggest that everything is but quiet. In the past 120 years, Accra has on three occasions been damaged by major earthquakes in 1906, 1939, and 1941 (Junner, 1941). Continued micro-seismic activity to date indicates that earthquake activity is far from over. The seismicity which occurred on the Volta river in 1971 was attributed to the Chain fracture zone which reaches Africa at Accra (Burke, 1971). Bouguer anomalies (Rechenmann et al., 1960 ) in the Accra area indicate a change in crustal structure within the continent across the eastern boundary of the West African craton. This change which resulted from the development of the Dahomy suture in an early Palaeozoic paratectonic orogeny, localized the Cretaceous transform that split Gondwana continent and became the Chain fracture zone (Burke and Dewey, 1971). Differential lateral motion across the Chain fracture zone at the continental margin is unlikely because the coast of Africa lies beyond the mid-Atlantic ridge offset.

The seismicity of the Volta Dam is more probably related to an abrupt change from crust of continental thickness to crust of oceanic thickness at the edge of the Ghana continental shelf (Burke, 1971). This does not seem to be a plausible explanation for the occurrence of the earthquakes in Ghana. The correspondence between the offset of the continental margin and the mid-Atlantic ridge on the Chain fracture zone is further evidence that Africa and the south Atlantic east of the mid-Atlantic ridge may be considered as part of the same rigid block (Burke, 1969). The occurrence, however, of seismicity near Accra with recently active faults indicates some comparatively differential motion across the fracture zone.

On December 22, 1983, a large earthquake occurred in Guinea further west of Nigeria in an area which was previously considered aseismic (USGS location 11.93 S and 13.60 W). The magnitude of the Guinean earthquake was M = 8.2 and was followed by about 1,000 aftershocks. The main shock was felt over an area of about 15 km. Several lives and property were lost on that occasion. The epicenter of the earthquake was located in a region bordering the West African craton at the southern end of the Mauritanides fold belt and at the edge of the Bowe basin characterized by non-metamorphic sedimentary layers (Dorbarth et al., 1983). Earthquakes have been reported in Guinea during the century mainly in the area and to the north of Cape Verde Islands.

Further east, Seiberg (1932) reported five earthquakes from Cameroon of which two were associated with the Cameroon mountain volcano and two including the largest had epicenters at Kribi ($10^0$ E, $4^0$ N), 200 km to the south. Many volcanic eruptions have been observed in recent times in the Cameroons which is adjacent to the northeastern and southeastern parts of Nigeria such as Gongola State. On August 21, 1986, the lake Nyos erupted. Cattle were killed and the flow of gas down the river caused 1,700 deaths among the local population. Lake Nyos volcano has been very active in the past. Similar gas explosions had taken place in 1954, 1982, and 1984. The outburst may be associated with a phenomenon in which the lake turns over under the influence of a minor external stimulus such as a storm or earthquakes.

The Cameroon volcanic zone which developed in the Neogene times is characterized by alkaline, mainly basaltic volcanics, is more than 1,100 km long, half on land and half in the ocean and is a major structural feature of the Gulf of Guinea, but the fracture zones because they seem to have controlled the distribution of Cretaceous and Tertiary sedimentary basins may be more fundamental (Burke, 1969). The Cameroon line cuts across a sedimentary basin and although there is a continuous history of Cenozoic magmatic activity in Cameroon, the volcanoes which make up the line are very young. The Cameroon structures appear to be tensional features related to the contact of oceanic fractures with the continent.

## CONCLUSION

Cenozoic volcanism may be ascribed as the triggering mechanism for the earthquakes in certain parts of Nigeria such as the Benue Valley, although this process is not well understood. Similarly, it is uncertain as to the cause of the earthquakes in other parts of the country. In any region, micro-earthquakes are much more frequent than larger events. A fundamental question is the relationship of small to large earthquakes. Can observations of micro-earthquakes (defined as those of magnitude less than 4) give information about large destructive earthquakes (of magnitude 7 or 8)? Small earthquakes are now monitored in several parts of the world. Unfortunately, neither fixed or temporary seismic arrays have been installed in Nigeria to monitor these micro-earthquakes. It is therefore extremely necessary to deploy seismic instruments in order to catalogue epicenters and magnitudes of these micro-earthquakes in Nigeria. Such masses of data need to be collected and painstakingly analyzed before a thorough understanding of the tectonics of these regions could be made.

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