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Possible Mechanisms for Nigerian Intraplate Earth Tremors

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Abstract

A total of 15 earth tremors have been recorded in Nigeria. Possible mechanisms for these intraplate tremors were examined. A regional stress created by the West African Craton, and Congo Craton with an inferred principal stress acting WNW—ESE is seen as one of the possible causes of the intraplate tremors. Inhomogeneities and zones of weakness in the crust created by the various episodes of magmatic intrusions and other tectonic activities were also considered as sources of the seismicity in the country. The spatial distribution of the tremors defined mostly northwest-southeast lines contrary to earlier theories that the tremors occurred in the inland extension of the northeast-southwest oceanic faults. Possible fault systems were inferred based on the spatial distribution of the earth tremors: Yola-Dambata, Akka-Jushi and Warri-Ijebu Remo systems.

1.0 Introduction

Nigeria is not situated on any known seismic belt, yet between 1933 and 2000 Nigeria experienced 15 earth tremors 3 of which occurred in 1984 (Table 1). The first recorded earth tremor in Nigeria occurred in Warri in 1933. This was followed three years later in 1936 by the tremor that shook Lagos and its environs. In 1961, a tremor was reported around Ohafia area but some authors hold that this was a slope movement rather than an earth tremor. The most severe of the tremors occurred in 1984 around Ijebu Ode (Ajakaiye, 1989). In 2000 another tremor occurred in the town of Jushi Kwari (Eze, 2007). These tremors show that Nigeria may not be as aseismic as previously thought. Major intraplate earthquakes are rare, however, their occurrence is often unpredictable and can result in high consequences in terms of both life-safety and economic loss. Consequently the issue of intraplate seismic hazard is attracting increasing attention

Table 1: Earth Tremors in Nigeria

Date	Town	Longitude	Latitude
1933	Warri	05° 45' E	05° 31' N
June 22, 1939	Lagos	03 °23' E	06 30' N
July 2, 1961	Ohafia	07° 47' E	05° 37' N
July 1, 1975	Dambata	08 °31' E	12° 25' N
1981	Kundunu	08° 24' E	11° 48' N
July 28, 1984	Ijebu Ode	03° 55' E	6° 48' N
August 2, 1984	Ijebu Remo	03° 22' E	07 ° 11' N
December 8, 1984	Yola	12° 27 E	09° 14 N
1985	Kombani Yahaya	11° 00' E	10° 02' N
1986	Obi	08° 46' E	08° 22' N
January 27, 1987	Gembu	11° 15 E	06° 42' N
March 19, 1987	Akko,	10° 57 'E	10° 17 N
May 1987	Kurba	10° 12' E	11° 17' N
June 27, 1990	Ibadan	03°58"E	07°22'N
August 2000	Jushi-Kwari	07° 42' E	14° 03' N

Sources: Ajakaiye *et al.*, (1984); Onouha, (1985); Eze, (2007).

2.0 Geological / Tectonic Setting

About two-thirds of Nigeria's landmass is underlain by the Pre-cambrian basement complex consisting of gneisses, migmatites, schist, and various metamorphic rocks and granites (Figure 1). These are in places intruded and interspersed by the "Older granites" which originated in the Pan-Africa Orogeny (Olujide and Udoh, 1989). Basement Complex rocks outcrop in four main areas of the country: north of Rivers Niger and Benue, covering parts of Kaduna, Plateau, Bauchi, Kano and Sokoto States; southern Nigeria, covering the greater parts of Kwara, Oyo, Ogun; and Ondo States; southeast Nigeria, spanning the northern parts of Cross Rivers State and as far north as Yola; and north of Benue River in Gongola State. These crystalline basement rocks have been subjected to deformation of different intensities throughout the geological period. Consequently, North-South (N-S), Northeast-

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Southwest (NE-SW), Northwest-Southeast (NW-SE), North northeast-South southwest (NNE-SSW), North northwest-South southeast (NNW-SSE) and to a lesser extent, East-West (E-W) fractures have developed (Olujide and Udoh, 1989).

The Basement rocks are overlain by Cretaceous and Tertiary sediments of the seven major sedimentary basins, viz, the Calabar Flank, the Benue Trough, the Chad Basin, lullemmenden (Sokoto) Basin, the Dahomey Basin, and the Niger Delta Basin. Sedimentary successions in these basins are of middle Mesozoic to Recent age (Kogbe, 1989). The Niger valley is possibly a graben and the Benue a sinistral shear zone that may be part of a fracture zone within the Pelsium Megashear system (Sheidegger and Ajakaiye, 1985). The Benue trough has also been considered as a "failed" rift since it contains no ophiolites (Nwachukwu, 1972).

In some cases the Cretaceous sediments are cut by some major faults which may have been the result of the reactivation of post Pan-African fractures (Merki, 1970). It has been suggested that the Dahomeyan Basin is bounded by the Romanche Fracture zones to the west and the Chain fracture zone to the East (Wright, 1976; Hastings and Bacon, 1979; Ige *et al*., 1985). Both fracture zones trend approximately in the northeast-southwest (NE-SW) direction.

Some of the important fault systems in Nigeria are the Ifewara, Zungeru, Anka and Kalangai fault systems. They are interpreted to have resulted from transcurrent movements (Garba, 2003). Adepelumia *et al*., (2008) conducted an integrated geophysical survey across a prominent zone of weakness clearly observable in Landsat.

Multispectral Scanner (MSS) and Side-looking airborne radar (SLAR) images in the Precambrian basement complex of southwestern Nigeria and confirmed the existence of the supposed Ifewara shear zone formed by shearing activities during Late Precambrian times. They also identified a NNE-SSW trending fault system in the area. The 250 km long NE-SW trending Ifewara fault zone has been shown to be linked with the Atlantic fracture system (Adepelumia *et al*., 2008). Burke *et al*., (1977) and Hubbard (1975) believe that the pronounced age differences on both sides of the fault zone suggest that the zone may indeed be a suture of Kibaran age.

There are also many mid-Atlantic ridge transform fracture zones (St. Paul, Romanche, Charcot and Chain fracture zones) in the Gulf of Guinea which many believe form part of the Pelusium Megashear system that cuts across the continent of Africa from the West Africa Coast to the Nile basin in NE Africa (Neev and Hall, 1982; Ajakaiye *et al*., 1982). The compressional trough which follows the line has been ascribed to an obligue collision between a NW African plate and a central plate consisting of southern and eastern Africa, the Arabia Peninsula and the Levant (Neev and Hall, 1982).

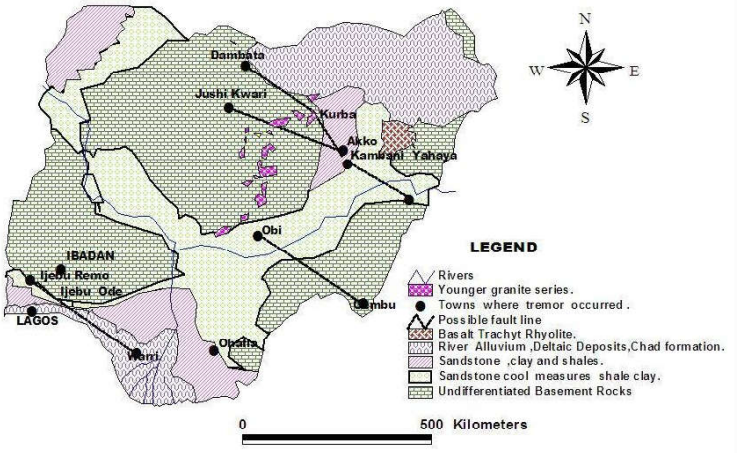

Figure 1: Geological Map of Nigeria Showing Location of Earth Tremor

3.0 Probable Causes of Nigerian Earth Tremors

The possible mechanism for the Nigerian earth tremors has been attributed to the locations of earth movements associated with NE-SW trending fracture and zones of weakness extending from the Atlantic Ocean into the country (Ajakaiye *et al.*, 1986, Ajakaiye *et al.*, 1987). Burke (1969) has also suggested possible relationship between the epicenters of some of the West African earthquakes and continentward extensions of oceanic fracture zones. Onuoha, (1988) attributed the tremors to partial reactivation of fossil plate boundaries. The spatial alignment of the earth tremors in Nigeria however defines a northwest-southeast (NW-SE) trend (Figure 1) and these tremors are cannot be said to be associated with the NE-SW trending extension of the Atlantic Oceanic fractures into the landmass. The tremors have most likely been caused by regional stress and zones of weakness in the crust or transfer of stress from plate boundaries.

3.1 Regional Stress

Nigerian Basement Complex rocks occur between the West African Craton, and Congo Craton. Murat (1988) inferred a principal stress acting WNW—ESE in the basement rocks. This is in concordance with the geographical location of the cratons as the sources of compression which are also in a WNW — ESE direction with respect to the Nigerian Basement Complex. Broad-scale uniform regional stress like this can generate intraplate earthquakes on low-strength pre-existing faults in the upper crust. This agrees with the regional stress models of Sykes, (1978); Iio and Kobayashi., (2002); Johnston and Kanter, (1990) and Zoback, (1992). The alignment of the tremors approximates to the direction of the principal stress. This is also one of the major fracture zones reported for the basement rocks of Nigeria (Olujide and Udoh, 1989).

3.2 Zones of Weakness

Cretaceous volcanics are recognized in sedimentary basins of Nigeria as pyroclastics, microdiorite sills and basalt dykes (Nwachukwu, 1972; Benkhelil, 1986). When a magmatic intrusion is present in stable rock the difference in geophysical properties can cause localised stress concentrations particularly when the intrusion is weaker than the surrounding rock. Initially the mafic intrusion is more rigid than the surrounding rock. Over time, however, the intrusion can become much weaker than the surrounding rock. Campell, (1978) have shown that inhomogeneities in the continental crust by this rock association can cause local stress concentrations. Kano, Bauchi and Yola have been intruded during the Proterozoic to Palaeozoic volcanic activity associated with the Pan-African orogeny. Rock intrusions in parts of the sedimentary basins of Nigeria may have created enough local stress concentration to initiate or predispose the areas to seismicity.

The zone of weakness model proposed by Sykes (1978) suggested that intraplate seismicity occurs where the crust has been weakened by previous tectonic activity. The Abakaliki and Benue Troughs are regarded as examples of failed rift arms following the opening of the South Atlantic. The troughs contain folded and unfolded mainly Cretaceous sediments which were deposited in two late Mesezoic rift troughs which formed the third arm of the Niger Delta Triple Junction (Merki, 1970). Extensional stress, due perhaps to upwelling magma beneath the region, must have deformed the crust and created faults. After the extensional sets ceased, the weakened crust was covered with sediment over millions of years. Over geologic time, these zones were incorporated into mid-plate structure and became subject to tectonic compressive stresses (Short and Stauble, 1967). Under stress, the previously fractured rock will fail before the pristine rock leading to intraplate tremors. Johnston and Kanter (1990) have similarly found that 49% of all intraplate earthquakes occur near ancient failed rifts or passive margins even though only one quarter of all stable continental crust is of this type.

3.3 Stress Transfer from Plate Boundaries

Stresses built up around plate boundaries could travel toward the centre of the plate triggering intraplate tremors especially in pre-existing faults. The coastal area of Nigeria lies in close proximity to the boundary between the African plate and South American plate. Some of the tremors that occurred in the coastal areas of Nigeria could have been possibly initiated by this process.

4.0 Conclusions

Nigeria is one of the stable continental crusts that have experienced some degree of seismicity. The earth tremors in Nigeria are distributed among the basement complex and sedimentary basins (Figure 1). They are concentrated along the south western and north eastern to north central parts of the country. The tremors lie in the southeast- northwest orientation. Any future occurrences of earth tremors in the country are likely going to occur along these inferred fault lines. Possible mechanisms for these intraplate tremors have been examined to include regional stresses created by Nigeria's position between two cratons and zone of weakness resulting from magmatic intrusions and other tectonic activities in the sediments.

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