Journal of the Nigerian Association of Mathematical Physics
Volume 55 **(February *2020 Issue*), pp109 –114**

SEISMICITY IN NIGERIA: THE NORTH CENTRAL NIGERIA 2016 TREMOR CASE STUDY

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Abstract

The Kaduna tremors that occurred in Jaba local government area of Kaduna state on 11th and 12th September 2016 were the most significant earthquakes in North Central Nigeria. An evaluation of the tremors was carried out with data retrieved from four operational seismological stations in Nigeria. With the aid of the three-circle and chord method an epicenter location of around latitude $10^{o}05'30.10"$N and longitude $8^{o}00'30.01"$E was estimated for the 11th September tremor and epicenter location of latitude $10^{o}00'40.02"$N and longitude $8^{o}06'45.05"$E for the 12th September event with an origin times of 12:28:16 GMT and 03:10:41 GMT for the respectively events. The local magnitudes were 5.0 and 4.9 for the11th September and 12th September tremors respectively using the Richter nomogram. The probable trigger for the seismic events is attributed to the reactivation of the Northeastern portion of the Ifewara-Zungeru fault, an over 550km long NNE-SSW trending fault.

***Keywords*:** Kaduna tremor, Earthquake, Ifewara fault, Zungeru fault, Seismicity.

1.0 Introduction

The first recorded earth tremor in Nigeria occurred in Warri in 1933 [1]. One of the most severe tremors occurred in 1984 around Ijebu-Ode [2]. In 2000, another tremor occurred in the town of Jushi-Kwari [3]. The intensity of these seismic events ranged from III to VI, on the Modified Mercalli Intensity Scale. Of these events, only the 1984 tremor at Ijebu-ode, the 1990 at Ibadan, 2000 at Jushi-Kwari were instrumentally recorded in the past. They had body wave magnitudes ranging from 4.3 to 4.5, local magnitudes between 3.7 to 4.2 and surface wave magnitudes of 3.7 to 3.9 [1]. The possible mechanisms for these intraplate tremors could be due to the regional stress created by the West African Craton [4]. Inhomogeneities and zones of weakness in the crust created by the various episodes of magmatic intrusions and other tectonic activities also were considered as sources of seismicity in Nigeria. Two theories were considered as the origin of the seismicity in the country, the possible faults systems were inferred based on the spatial distribution of the Earth tremors Yola-Dambata, Akka-Jushi and Warri– Ijebu Remo systems [5]. Most of these fault systems are trending northwest–southeast (Figure 1). The second assertion was that the tremors occurred in the inland extension of the northeast-southwest originating from the Atlantic Ocean and that possibly causes the activities along the Ijebu-Ode and Ibadan axis which is inferred to be associated with the Ifewara-Zungeru fracture systems [4]. The causes of Earth tremors in Nigeria have also 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 as reported in [6, 2].

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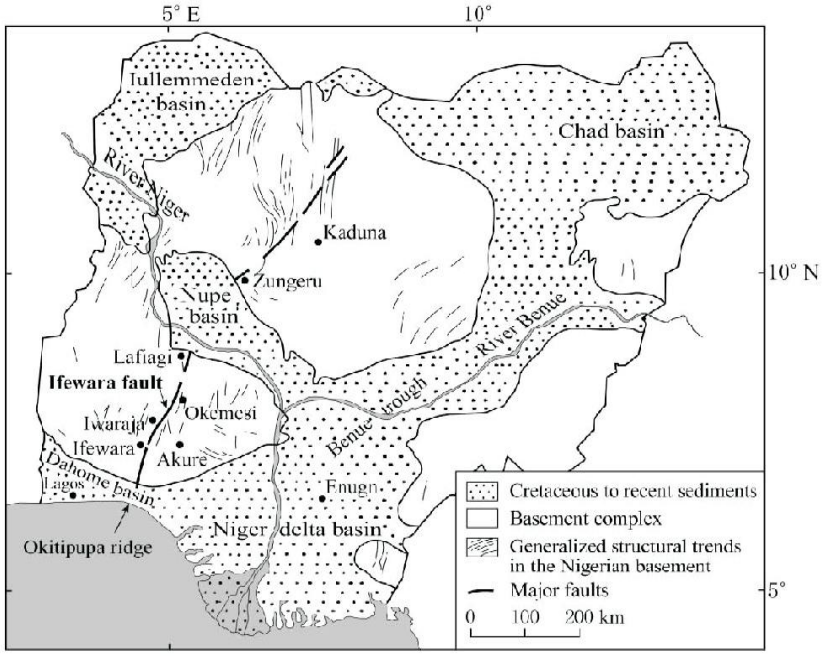

Figure 1: Location of the Zungeru-Ifewara fault within Nigeria [1]

Apart from being located within the intraplate area, Nigeria's land mass is made of Precambrian to Early Paleozoic crystalline basement rocks, about half of which is covered by sedimentary rocks of Cretaceous to recent age (see figure 1). These crystalline basement rocks have been subjected to deformation of different intensities throughout the geological period. Consequently, North-South (N-S), Northeast-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 [7] .

This study seeks to evaluate the Earth vibrations felt in the North central region of Nigeria on 11th and 12th September 2016. The seismic energy transmitted were picked up and recorded by four seismological stations in Nigeria. No lives were reportedly lost but damage was caused to roads and several buildings in the community. The tremors were geologically significant because it is widely accepted that the Nigerian landmass should be free from seismic activities as it lies on the relatively stable African plate which is far from the major seismicity zones of the world.

2.0 Material and Methods

Seismograms for both events were recorded by the seismological stations operated by the Centre for Geodesy and Geodynamics, Toro, Nigeria located in Ile-Ife (IFE), Kaduna (KAD), Abakaliki (BKL) and Nsukka (NSU). The seismogram data from the Nsukka station was greatly distorted by seismic noise from the environment because the station was built on poorly consolidated sediments, thereby making the measuring instrument less sensitive to ground vibrations. The data used for this analysis were recorded in the Mini SEED format and were converted to PDF format using Matlab software. Data from the four seismic stations were used for locating the epicentre of the 11th and 12th September earthquakes. The Local magnitude was computed in this study using the Richter nomogram. The P-wave and S-wave travel time curve technique was adopted using the lag time to obtain the distance of each station from the epicentre of the earthquake. To locate the epicentre of the local events, the triangulation technique that employes the three circle and chord method was adopted. Triangulation requires seismic data from three stations and involves using the epicentre distance of those stations read off the travel time curve as the radii to construct three circles on the map of the region around the three stations. These circles would intersect at the location of the Earthquake.

3.0 Results and Discussion

The result of the three circle and chord triangulation method gave epicentral location around latitude $10^{o}05'30.10"$N and longitude $8^{o}00'30.01"$E for the 11th September earthquake (figure 2) and epicentral location of latitude $10^{o}00'40.02"$N and longitude $8^{o}06'45.05"$E for the 12th September earthquake (figure 3). The origin time of the 11th September event was around 12:28:16 GMT while the origin time of the 12th September event was around 03:10:41 GMT. The errors in origin time, latitude and longitude are respectively: ±00:00:04, $00^{o}00'30"$(Table 1 and 2)

The epicentral location of both events lies close to the Ifewara-Zungeru mega-structure which is an over 550km long NNE-SSW trending fault stretching from the south just east of Ijebu-Ode, through Ifewara and Okemesi to the south western edge of the River Niger around Lafiagi. According to [8], the Ifewara fault in the southwest and the Zungeru/Kalangai fault in the north and north central parts of Nigeria are by far the most prominent lineament system in Nigeria. This fault zone has been shown to be linked with the Atlantic fracture system [4]. The dynamics of the Atlantic fracture zones have been suggested to be responsible for the seismic activities experienced in the areas [1] .

From the triangulation done on the geological map of Nigeria, it is seen that the epicentre of the earthquake falls within the Nigerian Precambrian basement complex terrain (See figure 2 and 3) which is a region of the regional Dahomeyide fold belt [9] . It is composed of Gneisses, Schists and Older Granites also known as the undifferentiated basement complex. Thus, it is not excluded from the structural and deformational episodes that are known to have pervaded the terrain.

Table 1: Arrival times of P- and S-wave, lag time, epicentre distance, travel time and onset time for seismic stations 11th September 2016

STATION	P-wave arrival time	S-wave arrival time	Lag time	Epicentre Distance	P-wave travel time	S-wave travel time	P-wave Onset Time	S-wave Onset Time
Abakaliki	12:29.02	12:29.36	00:00.34	340km	00:00:43	00:00:80	12:28:19	12:28:16
Kaduna	12:28:29	12:28:33	00:00.14	140km	00:00:17	00:00:32	12:28:12	12:28:01
Nsukka	-	-	-	-				
Ife	12:29:15	12:29:57	00:00.42	420km	00:00:55	00:01:40	12:28:20	12:28:17

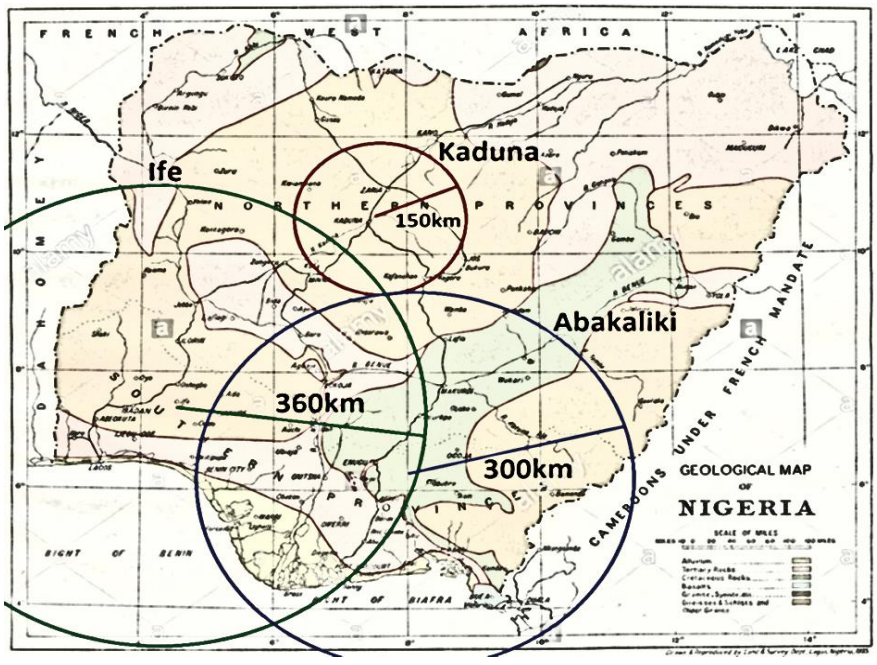

Figure 2: Geologic map of Nigeria showing epicentre location of the 11th September 2016

Table 2: Arrival times of P- and S-wave, lag time, epicentre distance, travel time and onset time for seismic stations 11th September 2016

STATION	P-wave arrival time	S-wave arrival time	Lag time	Epicentre Distance	P-wave travel time	S-wave travel time	P-wave Onset Time	S-wave Onset Time
Abakaliki	03:11.36	03:12.06	00:00.30	300km	00:00:37	00:01:10	03:10.59	03:10.56
Kaduna	03:11.00	03:11.15	00:00.15	150km	00:00:18	00:00:34	03:10.42	03:10.41
Nsukka	03:11.55	03:12.01	00:00.06	-				
Ife	03:11.54	03:12.30	00:00.36	360km	00:00:47	00:01:25	03:11.07	03:11.05

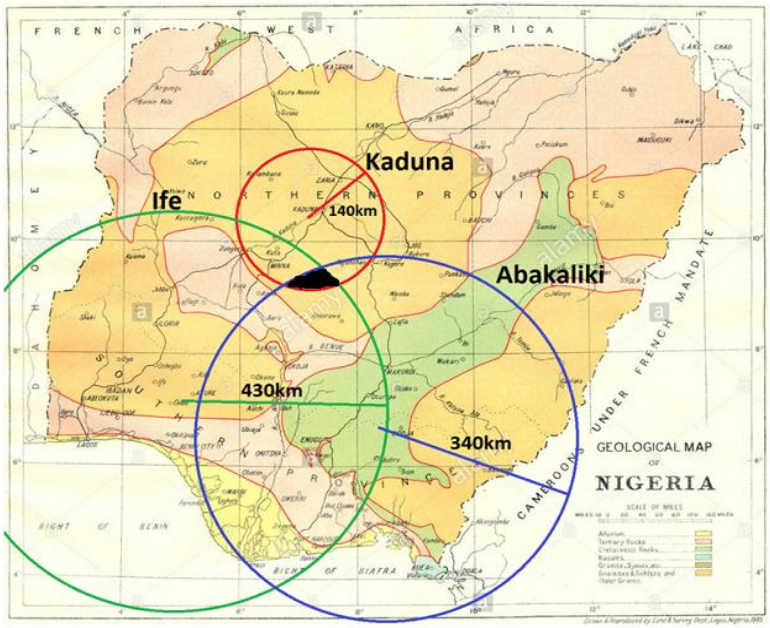

Figure 3: Geologic map of Nigeria showing epicentre location of the 12th September 2016 event

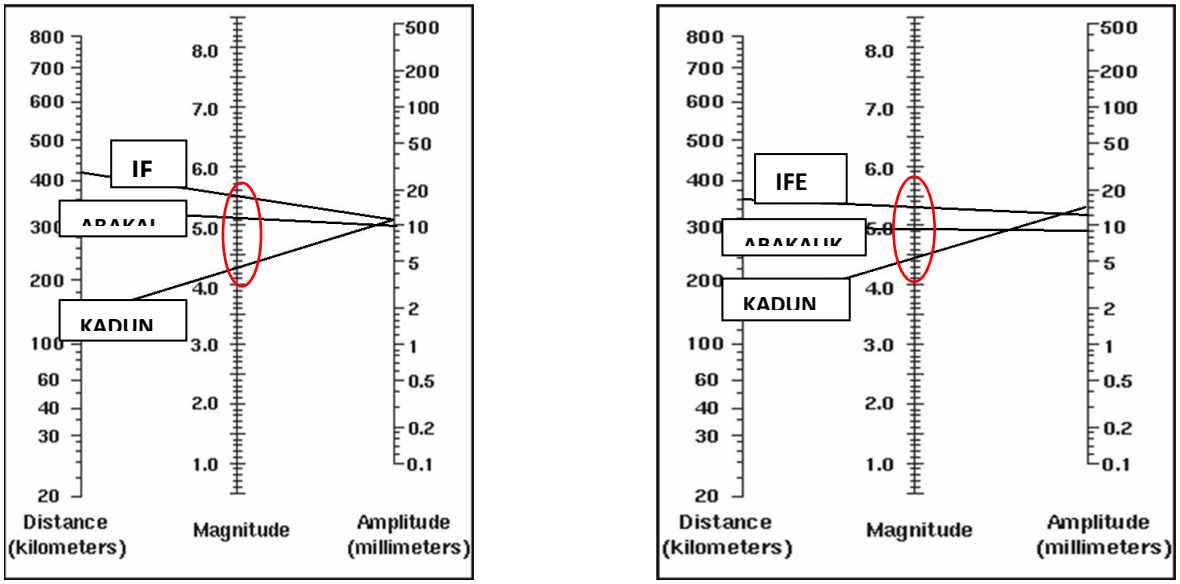

Figure 4: Richter nomograms for the 11th (Left) and 12th(Right) events respectively.

Table 3: Local Magnitude parameters 11th September 2016

STATION	Lag time	Epicentre Distance	Amplitude	Magnitude
Abakaliki	00:00.34	340km	10mm	5.2
Kaduna	00:00.14	140km	11mm	4.3
Ife	00:00.14	420km	11mm	5.6

Table 4: Local Magnitude parameters 12th September 2016

STATION	Lag time	Epicentre Distance	Amplitude	Magnitude
Abakaliki	00:00.30	300km	9mm	5.0
Kaduna	00:00.15	150km	14mm	4.4
Ife	00:00.36	360km	12mm	5.4

The parameters from the seismogram used estimate the magnitude of the events are presented in table 3 and 4.The local magnitude for the event of 11th September is about 5.0 (average magnitude from three stations) while the local magnitude for the event of 12th September is about 4.9 (average magnitude from three stations) on the Richter magnitude scale (Figure 4).

The respective magnitude obtained for both events are classified as light or moderate tremor on the Richter scale and are often felt but only cause minor damage to structures.

4.0 Conclusion

The results of the analysis of the September 11th and 12th 2016 earthquake felt in parts of Kwoi, Jaba Local Government area of Kaduna state, Nigeria showed that the focus of the tremor lies around latitude $10^{o}05'30.10"$N and longitude $8^{o}00'30.01"$E for the 11th September earthquake and latitude $10^{o}00'40.02"$N and longitude $8^{o}06'45.05"$E for the 12th September earthquake. It was deduced that the epicentre of the earthquake lies very close to one of the major fracture zones that run through the country which studies have shown to be an extension of the Atlantic fracture zone into the continent. Thus, a good understanding of the seismotectonics signature obtained from the recorded seismicity in Northern Nigeria is reported.

5.0 References

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