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Earthquake Dynamics in Nigeria: Insights, Challenges, and Preparedness Measures

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Nigeria is not a country chiefly linked with earthquake. However, there have been records of earthquake occurrences in the past. This dismissed the old believe that the country was aseismic. Even though Nigerian's seismic activity lies between moderate and low, seismicity in the county is not evenly distributed. The primary reason for the low occurrence of earthquakes in Nigeria is due to its location on the African continental plate, which is responsible for the tectonic activity. Most earthquakes occur at plate boundaries, where two plates meet and interact with each other. Earthquakes are a common occurrence in many parts of the world, and understanding their behavior is essential for predicting and mitigating their effects. This paper aims at addressing common questions pondered upon by Nigerians; what is earthquake? Is Nigeria susceptible to earthquake? Why is there earthquake in Nigeria? How and when does earthquake occur? It also torch light the instrumentation and management technique employed by the Centre for Geodesy and Geodynamics, National Space Research and Development Agency. Further, it highlights some safety measures to be observed before, during and after such a disaster. Since Nigeria is not entirely free from seismic activity, the country has been taking steps to improve its seismic monitoring and preparedness capabilities.

Keywords: Earthquake dynamics; magnitude intensity; seismic activity; earth tremor.

1. INTRODUCTION

Earthquake is a global natural phenomenon that poses a great threat to human lives and property. Hence, there is need to have adequate information about this form of natural disaster in order to proactively mitigate its effect. The fact that earthquake does not have any specific control for now, makes it a crucial subject of concern to researchers in the science community. Osagie [1] defines Earthquake or Earth Tremor as the trembling or shaking of the ground resulting from the unexpected or startling release of energy within the earth. "Its activities result from accumulated stresses within the outer 700 Km shell of the earth little was understood about earthquakes until the emergence of seismology at the beginning of the 20th century. Seismology, which involves the scientific study of all aspects of earthquakes, has yielded answers to such long-standing questions as why and how earthquakes occur" [2]. Earthquakes are experienced by most nations of the earth depending on their level of seismicity. While some nations are known for high seismicity, some are known for low and others none.

Nigeria amongst other nations of the earth has reflected dispersed seismic events within the period of 1933 to recent times. Many of the events that occurred in time past were not captured due to non-availability of seismic recording instruments [3]. Nigeria experiences occasional seismic events, at a lower frequency and intensity compared to regions located along active plate boundaries. The most seismically active areas in Nigeria are the Benue Trough, the Niger Delta region, and the northeastern part of the country. With the increasing occurrence and spread of Tremors in Nigeria, it is necessary to be armed with the knowledge of the causes, implication of the natural disaster and how best to minimize casualty [4]. Understanding earthquakes in Nigeria requires consideration of the country's geological context and seismic activity. Nigeria is located within the African Plate, which is relatively stable compared to other tectonic plate boundaries. However, Nigeria is not entirely free from seismic activity.

1.1 Seismic Waves

Laishram [5] defines Seismic waves as waves of energy that travel through the Earth's layers, and are a result of an earthquake. Seismic waves are simply waves generated as a result of energy release cause by an explosion or earthquake, vibration or any similar energetic source. There are mainly two types of seismic waves;

1. Body waves - Primary (P) waves and Secondary (S) waves: The primary (P) waves are the fastest waves; they travel through solid, liquids, or gases. They are compressional waves and the material movement is in the same direction as wave movement. Secondary (S) waves are slower than P waves; travels through solid only. They are shear waves and move material perpendicular to wave movement.

2. Surface Waves- Love waves and Rayleigh waves: Love waves are horizontally polarized shear waves existing only in the presence of a semi-infinite medium overlain by an upper layer of finite thickness. They travel slightly faster than Rayleigh waves.

Rayleigh waves travel as ripples with motions that are similar to those of waves on the surface of water. They are slower than body waves.

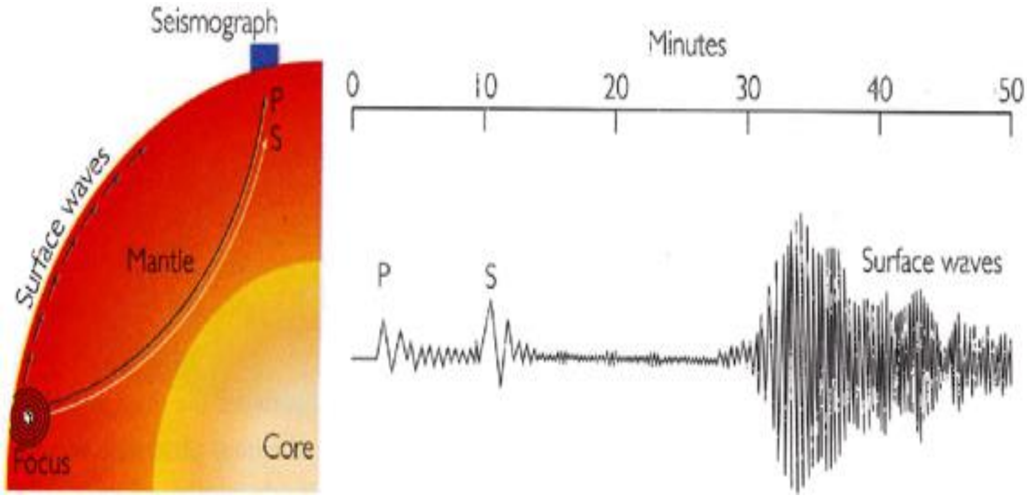


Fig. 1a. Diagram showing P-wave and S-wave

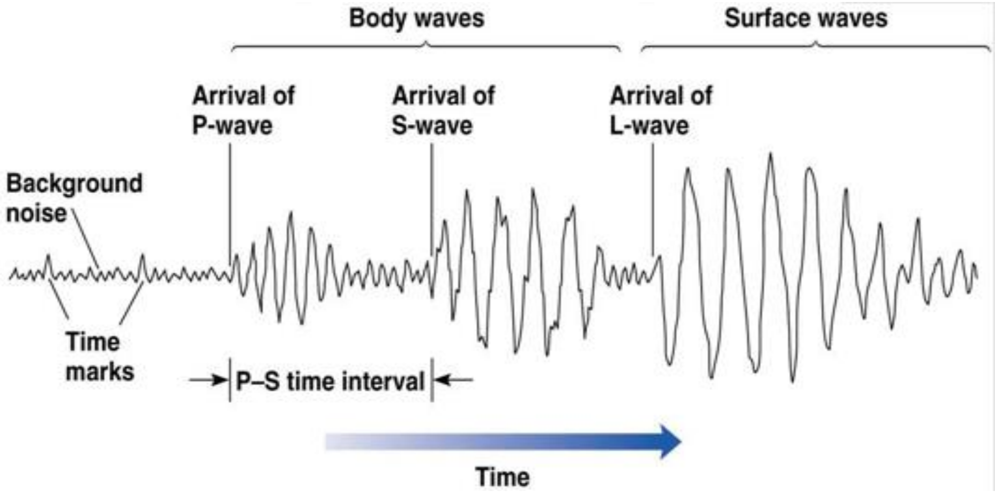


Fig. 1b. Seismographic recording of P, S and surface waves

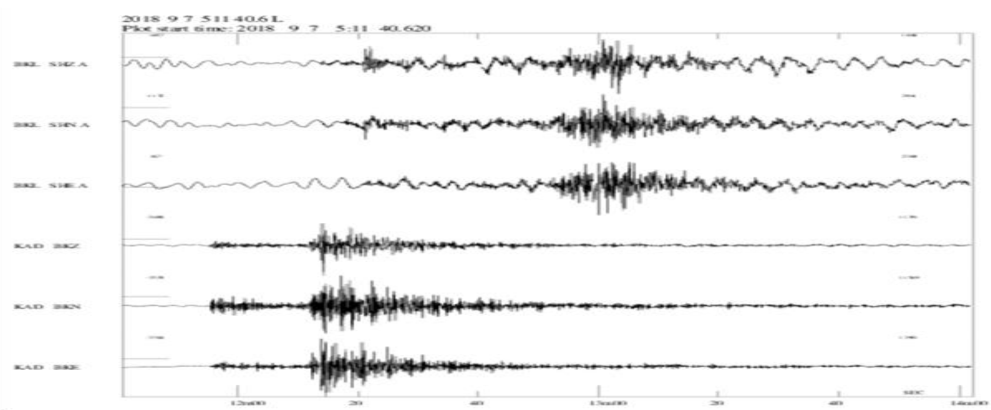


Fig. 1c. Seismograms of Abuja Earthquake (main shock) on the 7th September, 2018 (Source: CGG Toro)

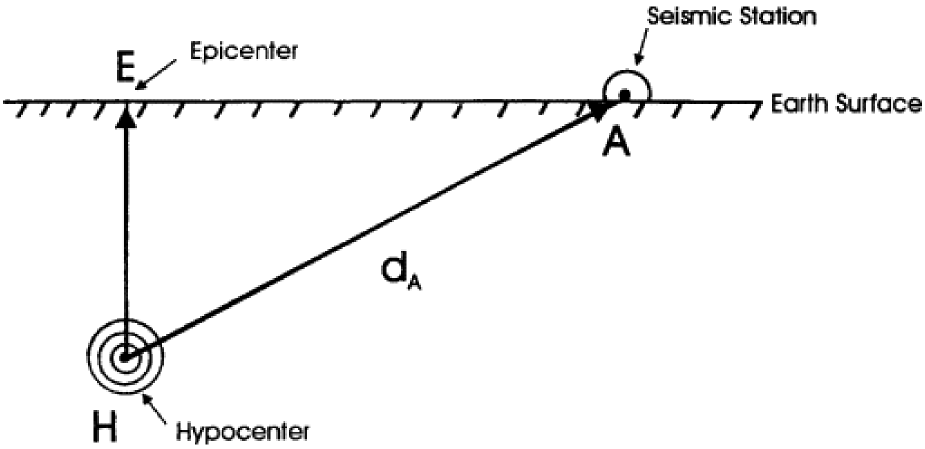


Fig. 2. Diagram showing Epicenter, Hypocenter, Earth Surface and Seismic Station
(Source: Leonid et al., 2000)

1.2 Locating Earthquake

Earthquake location is one of the most important tasks in practical seismology and most seismologists have been involved in this task from time to time. The earthquake location is defined by the earthquake hypocenter (longitude, latitude, and focal depth) and the origin time. To locate an earthquake, it is necessary to have correct readings of the arrival time of *P* and *S* waves at several seismic stations. The accuracy of the location depends on the number of stations and their distribution in space relative to the hypocenter. It is also necessary to have information about the velocity structure in the area as the travel time of the waves depends on the velocity [6]. Studies by Alabi et al. [7] states that 90% of all devastating earthquakes occur at fault lines between tectonic plates.

1.3 Epicenter and Hypocenter

The Epicenter of an earthquake is the longitude and the latitude of the earthquake. It is also the projection of the earthquake location on the surface of the earth. Table 1 shows the epicenters of Nigerian earthquakes. Hypocenter is the point where the earthquake originates. It is the focus of the earthquake. Most of the epicenters of Nigerian earthquakes were found to be in the south west.

2. GENERAL SURVEY OF EARTHQUAKES IN NIGERIA

Nigeria is situated on the West African Craton, which is a stable continental region. However, the country is also located in a region of active tectonics, where there is ongoing deformation and faulting. The Nigerian basement complex is composed of metamorphic and igneous rocks, which have been subjected to multiple phases of deformation. There are also sedimentary basins in Nigeria that have experienced tectonic activity. The complexity of the geological and tectonic conditions in Nigeria makes earthquake prediction challenging. There are many fault zones in the country, and the movements of these faults are not well understood. Additionally, there are many factors that can influence radon concentrations, such as soil moisture, temperature, and barometric pressure. These factors can make it difficult to interpret changes in radon concentrations as earthquake precursors [2].

Historical Earthquake in Nigeria were compiled from journals, personal communications with the natives of the associated areas and newspapers written from 1933 -2011.These developments in the nations' geological history brings to question the age long belief that Nigeria is seismically safe. The possible mechanisms for these intraplate tremors could be due to the regional stress created by the West African Craton [8]. Studies shows that these pockets of activities were felt in different parts of the country with the southwest region recording the highest number of events and moderate magnitudes of between 4 and 4.5 [9]. One of the most recent tremor happened in 2018 in Abuja, where the impact was reportedly felt in Maitama and Mpape. This event raised so much fear and questions in the heart of its residents, with people calling on the Government and relevant authorities for answers and explanation to what they have experienced. In response to that, a presidential committee was set up to investigate the tremor and detail of the event was contained in the report submitted to the presidency. Researchers have published their findings on the tremor via different scientific research platforms which can be easily access online. Also, Saki and Okitipupa experience tremors in 2021.

The states fall under fault zones, mostly basement terrains in lithology. From the occurrences recorded, other areas close to them are likely to experience it in future because the fault transcend from one area down to other places. Those areas specified with earthquake occurrences are basically faulted or shear zones, mostly basement environments not sedimentary terrains and those places extends beyond just a single town. Any little pressure along the convergent boundaries will cause tremor which the lava can only be seen along the openings (fault zones).

2.1 Intensity and Magnitude

The intensity of an earthquake is a qualitative measure of damage caused by earthquakes. Larger events give rise, generally, to higher intensity. For the same earthquake, the intensity scale must commonly use. However, the magnitude, M of an earthquake is a quantitative measure of its strength with regard to the energy released at the source. Any earthquake has a unique value of magnitude. Currently, there are several scales of earthquake magnitude [10]. The Centre for Geodesy and Geodynamics, Toro in Bauchi State, reports that the average value of intensities for Nigerian Earthquakes ranges from III –VI on the Modified Mercalli Scale. The ML is averaged at 3.7 – 4.2. Mp is averaged at 4.3 -4.5 and MS is averaged at 3.7 – 3.9 [11]. According to Saradj [12], "earthquakes with an intensity of III on the moment magnitude intensity scale, can be felt by most people. Furthermore, on Earthquake Magnitude Scale, 5.5 to 6.0 magnitudes will cause slight damage to buildings and other structures; 6.1 to 6.9 may cause a lot of damage in very populated areas; 7.0 to 7.9 magnitudes is major earthquake with serious damage; and 8.0 or greater magnitude is great earthquake and can totally destroy communities near the epicenter [13].

2.2 Focal Depth and Origin Time

The depth of focus from the epicenter, called Focal Depth, is an important parameter in determining the damaging potential of an earthquake. Most of the damaging earthquakes have shallow focus with focal depths less than about 70km. Distance from epicenter to any point of interest is called Epicentral distance [14]. The Origin Time of an earthquake is the actual time the earthquake occurred at the source.

2.3 Foreshock and after Shock

Foreshocks and Aftershocks are sometimes associated with earthquakes. Foreshocks precedes earthquakes and appear as preparation process prior to the nucleation and are smaller in magnitude and can only be determined after the main event. Aftershocks are secondary shocks produced after the main event as rocks adjust to the effect of the earthquake. The severity of earthquakes is determined by the depth, amount of displacement, and area of the rupture plane. The deeper the earthquake, the more powerful but less damaging. And the shallower the earthquake, the more dangerous and damaging especially in populated areas.

2.4 Eathquake Prone States in Nigeria

The Occurrence of tremors in Nigeria has been associated to the Ifewara-Zungeru fault which spans east of Ijebu-Ode in the south through Kalangai in north-western Nigeria. This Ifewara-Zungeru fault was responsible for all the tremors which have been experienced in Nigeria over the years [15].

In homogeneities 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 [8]. From study of the structural geology of Nigeria, states or towns that fall along the fault zones have high chances of seismic shift occurrences. These places are mostly basement terrains. The then Director General of National Space Research and Development Agency (NASRDA), Prof. Seidu Mohammed, who was also the chairman of presidential committee on the Abuja tremor, opined that Mpape in Abuja, Kwoi in Kaduna, Ijebu-Ode in Ogun, Shaki in Oyo and Igbogene in Bayelsa may likely be the epicentres of major earthquakes in Nigeria if precautions were not taken [16].

The earthquake occurrences in Kwoi, Kaduna state, Saki, Oyo State and Igbogene in Bayelsa State all in 2016 is also evidence that the aforementioned states are prone to major earthquake [17]. So far, from the records of the earthquakes occurrences in Nigeria (Table 1) from 1933 to 2018, the South Western region is said to be the weak zone in the country.

From the table above (Table 2), all the states listed have recorded one or two seismic events in the past. This is in conformity with a report by the Headquarters for Earthquake Research Promotion (2022) in Japan, which states that large-scale earthquakes have a tendency of happening repeatedly at the same place as in the past. The investigation of active faults shows that large-scale inland earthquakes also have repeated at the same fault as in the past. Although, Nigeria is yet to record any event of such great magnitude, the need for proper disaster alertness and management cannot be over emphasis.

Table 1. Earthquake occurrences in Nigeria

Year	Month	Day	Magnitude	Epicenter	Energy Released Joules
1933					
1963	12	21	5.0	Ijebu ode	199526231500
1981	04	23	3.0	Kundunu Village	1995262315
1984	07	28	6.0	Ijebu- ode	6309573445000
1984	07	12	4.0	Ijebu- ode	6309573445
1984	08	02	5.0	Ijebu-ode	199526231500
1985	06	18	4.0	KombaniYaya	6309573445
1986	07	15	3.0	Obi town	1995262315
1987	03	19	4.0	Akko	6309573445
1987	05	24	3.0	Kurba Village	1995262315
1988	05	14	4.0	Lagos	6309573445
1990	06	27	3.7	Ijebu- ode	2238751139
1990	04	05	5.0	Jerre Village	1995262315
1994	11	07	4.2	Dan gulbi	12589254120
1997			4.0	Okitipupa Ridge	6309573445
2000	08	15	3.0	Jushikwar Village	1995262315
2000	03	13	4.0	Benin	6309573445
2000	03	07	4.7	Okitipupa Ridge	7079457844
2000	05	07	4.0	Okitipupa Ridge	6309573445
2001	05	19	4.0	Lagos City	6309573445
2002	08	08	4.0	Lagos City	6309573445
2006	03	25	3.0	IfewaraZungeru	1995262315
2009	09	11	2.0	Close to Benin	6309573.45
2009	10	12	4.1	Close to Benin	8912509381
2011	11	05	4.4	ClosetoAbeokuta	2511886432
2016	07	10	4.0	Oyo State	6309573445
2016	08	10	3.0	Bayelsa State	1995262315
2016	09	11	3.0	Kaduna State	1995262315
2016	09	12	3.0	Kaduna State	1995262315
2018	09	07	3.0	Abuja	1995262315
2018	09	07	2.6	Abuja	501187233.6
2018	09	07	2.5	Abuja	354813389.2
2021	06	05	2.6	Okitipupa	501187233.627
2021	09	05	3.5	Saki	11220184543

Table 2. Earthquake prone States in Nigeria

S/N	STATE	EPICENTRE
1	Abuja	Mpape
2	Bayelsa	Igbogene
3	Kaduna	Kwoi
4	Ogun	Ijebu-Ode
5	Oyo	Shaki

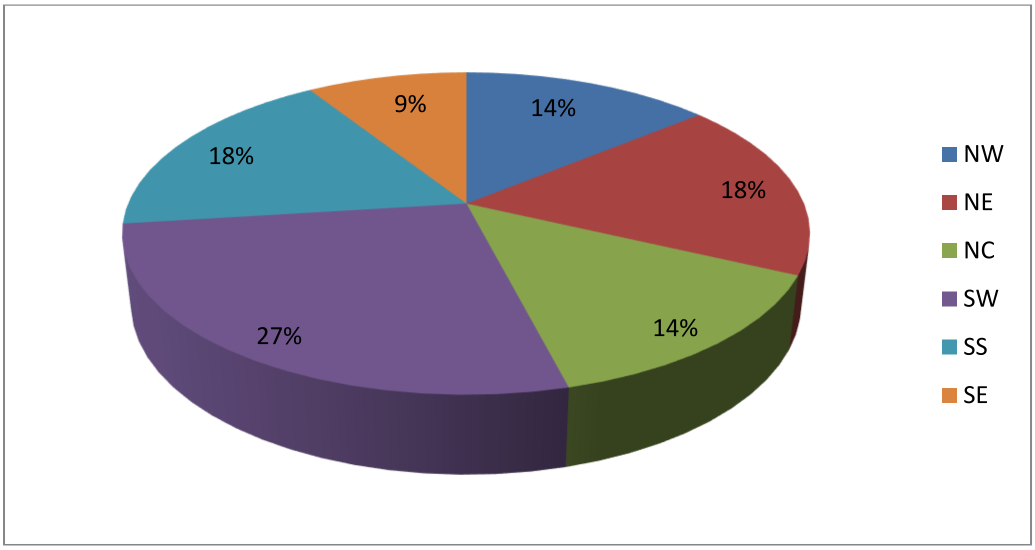


Fig. 3. Pie chart showing spread of Earthquakes occurrences by region in Nigeria

2.5 Earthquake Vs Earth Tremor

Earthquake and earth tremor are words interchangeably used to describe the irregular shaking of the earth surface resulting from the sudden energy release from the earth crust. Even though they both define seismic activity, they however have some slight disparities. This can be observed in their magnitude, intensity and impact.

An earthquake has magnitude above 5 on a moment magnitude scale while tremor has magnitude below 5 on same scale.

2.6 Earthquake Mechanism

Earthquakes are frequently associated with reports of distinctive sounds and lights. The sounds are generally low-pitched and have been likened to the noise of an underground train passing through a station. The occurrence of such sounds is consistent with the passage of high-frequency seismic waves through the ground. Occasionally, luminous flashes, streamers, and bright balls have been reported in the night sky during earthquakes. These lights have been attributed to electric induction in the air along the earthquake source [18].

Earthquakes are natural phenomena that occur when there is a sudden release of energy in the Earth's crust, leading to seismic waves that cause the ground to shake. The mechanism behind earthquakes is primarily related to the movement and interaction of tectonic plates, which are large sections of the Earth's crust.

The Earth's lithosphere, which includes the crust and the uppermost part of the mantle, is divided into several tectonic plates. These plates are constantly moving, albeit very slowly, due to the convective currents in the underlying semi-fluid asthenosphere. There are three main types of plate boundaries where significant seismic activity occurs:

Convergent boundaries: At convergent boundaries, two plates collide with each other. One plate is typically forced beneath the other in a process known as subduction. The subducting plate descends into the mantle, creating intense pressure and friction. Eventually, stress builds up along the plate interface, and when it exceeds the strength of the rocks, it is released in the form of an earthquake.

Divergent boundaries: Divergent boundaries are characterized by plates moving away from each other. As the plates separate, magma rises from the mantle to fill the gap, creating new crust. This process occurs along mid-ocean ridges or continental rift zones. The movement of plates and the associated volcanic activity can trigger earthquakes along these boundaries.

Transform boundaries: At transform boundaries, two plates slide past each other horizontally. The best-known example of a transform boundary is the San Andreas Fault in California, USA. The plates may become locked due to friction along the fault line, causing stress to accumulate. When the stress overcomes the friction, it releases suddenly, generating an earthquake.

The energy released during an earthquake propagates in the form of seismic waves. The earth is in a constant state of seismic activity, although, earthquakes do not occur in all geographical locations of the world. Their occurrences are restricted to well-defined areas, being more concentrated along plate boundaries [19].

2.7 Types of Earthquakes

There are four types of earthquakes reported by Laishram [5], these are:

1. Tectonic Earthquakes; occur when rocks in the earth's crust break due to geological forces created by movement of tectonic plates.
2. Volcanic Earthquakes; occur in conjunction with volcanic activity.
3. Explosive Earthquakes; result from the explosion of nuclear and chemical devices.
4. Collapse Earthquakes; are small earthquakes in underground caverns and mines.

2.8 Classification

Laishram [5] classified earthquakes according to the basis below:

1. Cause of origin

(i) Tectonic Earthquakes occur when the plates move against one another. This movement can create stress that causes the Earth's exterior shell, the lithosphere, to shift or break.
(ii) Non-tectonic earthquakes. The non-tectonic earthquakes are mainly of three types due to surface causes, volcanic causes and collapse of cavity roofs.

2. Depth of focus

(i) **Surface-earthquakes:** Surface-earthquakes are those in which the depth of the focus is less than 10,000 metres.
(ii) **Shallow-earthquakes:** The earthquakes with the hypocentre at a depth of 10 to 50.
(iii) Intermediate-focus earthquakes: When the earthquake is originated at a depth of 50 to 300 Kms.
(iv) **Deep-focus earthquakes:** The deep-focus earthquakes or the plutonic earthquakes are those with hypocentres located at depths more than 300 kms. Majority of the deep focus earthquakes originate between 500 and 700 kms.

3. Intensity and Magnitude of Earthquakes

(i) Rossi-Forrel's Scale (ii) Richter Scale (iii) Mercalli Scale
(i) Rossi-Forrel's Scale; the 1873 version of the Rossi–Forel scale had 10 intensity levels:

I. Microseismic tremor
II. Extremely feeble tremor.
III. Feeble tremor.
IV. Slight tremor.
V. Moderate tremor.
VI. Strong tremor.
VII. Very strong tremor.
VIII. Damaging tremor.
IX. Devastating tremor.
X. Extremely high intensity tremor.

(ii) Richter scale measures total amount of energy released by an earthquake; independent of intensity.
(iii) Mercalli Scale: Amplitude of the largest wave produced by an event is corrected for distance and assigned a value on an open-ended logarithmic scale.

3. PROBABLE CAUSES OF EARTH-QUAKE 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" [20]. The second assertion which was the earlier theory revealed that the tremors occurred in the inland extension of the north east- south west originating from the Atlantic Ocean and that possibly causes the activities along the Ojebu Ode and Ibadan axis which is inferred to be associated with the Ifewara- Zungeru fracture systems [8].

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" [15]. "The Stresses built up around

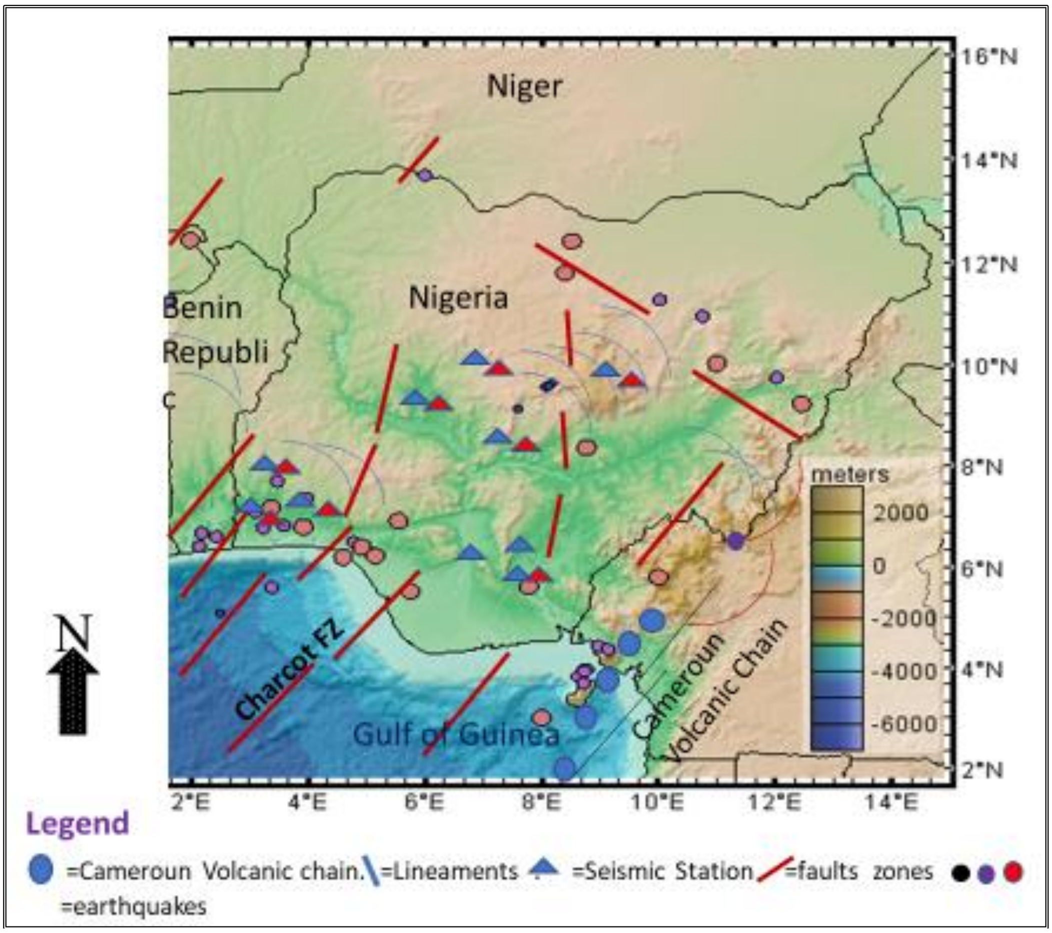


Fig. 4. Seismotectonic map of Nigeria (Courtesy: Kadiri U.A., 2019)

plate boundaries could travel toward the centre of the plate triggering intra-plate tremors especially in pre-existing faults.

Some researchers are of the opinion that human activities triggers earthquake. This is however, another area of debate among the seismology sphere. In support of such claim, Odeyemi [22] believes that Natural earthquakes are caused mostly by rupture of geological faults, but also by volcanic activity, landslides, mine blasts, and nuclear experiments. While most earthquakes are caused by movement of the Earth's tectonic plates, human activity can also produce earthquakes. Four main activities contribute to this phenomenon namely construction of large dams and buildings, drilling and injecting liquid into wells, coal mining and oil drilling.

4. INSTRUMENTATION/ MEASUREMENT

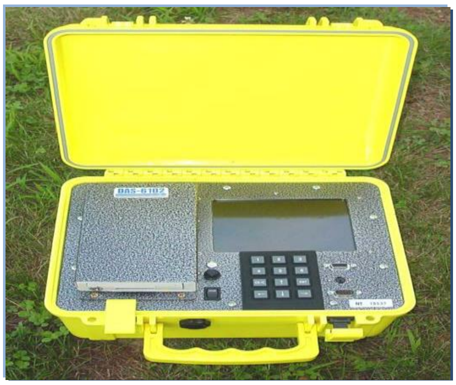
The Center for Geodesy and Geodynamics has been managing the Nigerian National Network Seismic Stations comprising of 7 operational stations equipped with 24-bit 4-channel recorders (digitizer and data logger) and broadband seismometers (EENTEC or Guralp) since 2006, after it was handed over by the National Agency for Science and Engineering Infrastructures. The equipment at each station include; DR-4050 data acquisition system, EP-105 broadband (60 seconds period) seismometer or 16 seconds period), seismometer Global Positioning System (GPS) Power source (Solar panels and 100 AH battery) New sets of equipment have also been procured; Guralp broadband sensor (120 seconds period). Three more stations (Ibadan, Oyo and Abuja) have been added to the existing stations.

A seismometer is a device that is sensitive to vibrations. It works based on the principle of a pendulum: a heavy, inert mass with a certain resistance to movement due to its weight is suspended from a frame by a spring that allows movement. The energy from any seismic activity excites this “proof mass” as it is called by geophysicist, making it vibrate.

These measurements are carried out by short period and broadband sensors, the short period sensors are specifically designed for local earthquake recordings with real or near real time analysis for micro earthquake detection while the broadband sensors record over a wider range such as the EP 105 and the Guralp sensors.

EENTEC EP105 Seismometer
(Source: EENTEC, 2002)

EENTEC SP400 Seismometer
(Source: EENTEC, 2002)



EENTEC DR4000 DAS
(Source: EENTEC, 2002)

EENTEC DR4050DAS
(Source: EENTEC, 2008)

Fig. 5. Picture of some CGG's seismic equipment

4.1 State of Nigerian Seismic Stations

The seismographic stations of the Center for Geodesy and Geodynamics (CGG) are some of the stations under the Nigerian National Network of Seismographic stations (NNNSS) operated and managed by CGG since 2006.

The aim and objectives of these stations are to monitor seismic activities in Nigeria using seismic monitoring facilities so as to provide information on areas susceptible to earthquake and to provide data to scientists.

Ten stations were planned to host the seismic equipment in monitoring areas susceptible to earthquake. They are: Obafemi Awolowo University, Ile-Ife, University of Ibadan, Ibadan, NASRDA H/Q premises, Abuja, Kujama, Kaduna, Minna, Federal Government Girl's College, Oyo, University of Nigeria, Nsukka, Nnamdi Azikwe University, Awka, Abakaliki and Toro. These Stations are to be networked and controlled from Toro Observatory.

Renovation has been concluded on seven (7) of the Vaults and seismic equipment have been procured and installed. They are: Kaduna, Ile-Ife, Abakaliki, Awka, Nsukka, Mina, Ibadan, and Toro. Data are already being generated which is being made use of all over the world (Fig. 2). Each station is equiped with EP- 105 BROADBAND TRIAXIAL SEISMOMETER which detects and measures the intensity of ground motion. For earthquake, the DR – 4000 MULTI-CHANNEL DATA ACQUISITION SYSTEM is employed in the recording, plotting and signal storage from the seismometer, computers and GPS.

The station at Kujama, Kaduna state was recently vandalized by hoodlums and some equipment were stolen. However, the Centre had made great effort and relocated the station to the Kaduna State Univeristy which is more secure. At the moment, there are Ten (10) stations working and transmitting real live data to the Toro observatory. Also, there is ongoing projects of establishing new stations to complement the existing ones.

In addition to the stations under CGG, there are other stations manage by the Nigerian Geological and Survey Agency (NGSA), and some private organizations.

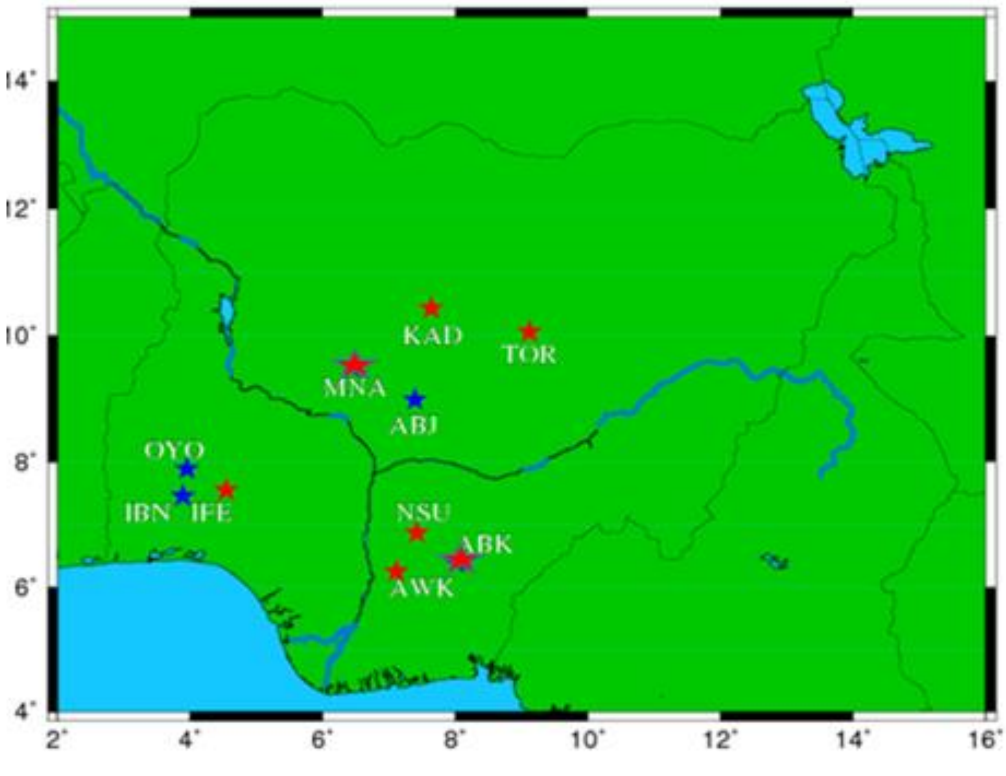


Fig. 6. Map of Nigeria showing the locations of the seismological stations
(Adapted after Kadiri U.A, 2019). Red stars = Old operational stations; Blue stars = newly installed stations

Table 3. Seismic stations in Nigeria under CGG

S/N	Station Name	Latitude	Longitude	Elevation (KM)
1	ILE-EFE	07°32.800′	04°32.815′	289
2	AWKA	06°14.561′	07°06.693′	50
3	NSUKKA	06°52.011′	07°25.045′	430
4	ABAKILIKI	06°23.453′	08°01.474′	82
5	TORO	10°03.303′	09°07.089′	882
6	KADUNA	10°26.101′	07°38.484′	668
7	MINNA	09°30.702′	06°26.411′	203

Table 4. Instrumentation at NNNSS

Parameters	EP105 (Broadband)	SP400 (medium period)
Operating principle	Proprietary Electrochemical Sensors; force-balanced	Proprietary Electrochemical Sensors; force-balanced
Output signals	2 horizontal, 1 vertical; velocity flat response	2 horizontal, 1 vertical; velocity flat response
Output swing:	±20 V differential; (40 V p-p)	±20 V differential; (40 V p-p)
Dynamic Range	142 dB	142 dB
Pass band	0.033 – 50 Hz	0.067 – 50 Hz
Generator constant	2000 V/m/s	2000 V/m/s
Maximum installation tilt	±10 ˚	±10 ˚
Mechanical resonances	None	None
Environmental	Waterproof, submersible (1m)	Waterproof, submersible (1m)
Temperature range	-12 to + 55 ˚C	-12 to + 55 ˚C
Housing material	Aluminum	Aluminum
Weight	~8kg	~8kg
Power	10-15 Vdc; (Nominal 12Vdc); 30 mA	10-15 Vdc; (Nominal 12 Vdc); 30 mA 12Vdc); 30mA
	Guralp -S/N of sensor and digitizer = T36351/2777 -Sample rate for the main seismic channels = 100sps -Digitizer sensitity = 2000 v/ms-1 -Gain = 1 -Generator Constant = 5000 -Digitizer = TM3200	

5. EFFECTS OF EARTHQUAKE IN NIGERIA

Wuyep et al. [2] reported that multiple minor quakes have been experienced in some parts of the country. The first widely reported incident of an Earth tremor in Nigeria was in 1933. Other events were reported in 1939, 1964, 1984, 1990, 1994, 1997, 2000 and 2006. The intensities of these events spread from III to VI based on the Modified Mercalli Intensity Scale. Of these events, only the 1984, 1990, 1994 and 2000 events were instrumentally recorded. They had body wave magnitudes ranging from 4.3 to 4.5, local magnitudes between 3.7 and 4.2, and surface wave magnitudes of 3.7 to 3.9. When these events occurred, there were no functional seismological observatories in Nigeria. However, that has now changed with the establishment of a seismographic network managed by the Centre for Geodesy and Geodynamics (CGG), Toro, Nigeria. Currently, the network has four operational stations equipped with 24-bit 4-channel recorders and broadband 30-second seismometers. Attempts are being made to establish more stations and migrate to real-time collection of seismic data using the general packet radio service (GPRS) technology as well as automatic location of events. Remote sensing, geological and geophysical studies have revealed the presence of a NNE-SSW trending Ifewara-Zungeru fault zone which is linked with the Atlantic fracture system. The dynamics of the Atlantic fracture zones have been suggested to be responsible for the seismic activities experienced in the areas. When an earthquake occurs, the trail of the adverse resulting impacts is not limited to the moment of its occurrence. The impact of an earthquake occurred in a nation can lead to a major setback in her development and her economic status and this can even linger for years after the event had occurred based on the magnitude of the earthquake [23,24].

Some of the effects of earthquake in Nigeria as recorded previously are:

1. Damage to structures
2. Liquefaction
3. Trauma
4. Loss of Properties

Fig. 7. (a) Collapsed building at Igbogene, (b) Crack and subsidence on a coal tarred road at Igbogene, Bayelsa State (2016), (c) Building almost collapsing at Ishiayi, Rivers State (2016),(d) Building showing caved-in ceiling in one of the communities, (e) Cracked wall from impact of tremor in Kwoi Kaduna state 2016, (f) Building with cracked wall at Mbiama, Rivers State (2016)

From the assessment of some areas within the affected states, it was observed that some buildings have cracks down from the foundation to the top of the buildings. It extends even to lintel level in some cases. Builders carry cement and iron rods, chock it with cement and cover it. Those cracks are fault zones. A careful examination of the ground shows an alignment of crack on the floor running even down to the next house. That's a fault zone, its negligible seismic shift that occur which opens in that way, but if it persist and heavy tremor occur again, the crack will keep deepening [24,25].

6. EARTHQUAKE MANAGEMENT

Our understanding of earthquake behavior would contribute to the development of more effective earthquake prediction and mitigation strategies. The recent trend of earthquakes/tremors in Nigeria is an indication that seismic activities within the country are increasing and urgent measures need to be adopted to avert devastating consequences of

big earthquakes in the most populous black nation in the world. The seismic events whose vibrations were felt heavily close to epicenters at the respective communities such as; Ijebu Ode, kwoi, Obi town, Kurba village , Dan gulbi amongst others are now causing the entire country and indeed, the global seismological community a great concern [26].

While Nigeria is not known for frequent earthquakes, it is still important to understand the potential risks and take measures to prepare and mitigate the impact of earthquakes. Building codes and standards can be developed to ensure that structures are constructed to withstand earthquakes, and public awareness campaigns can be conducted to educate citizens on earthquake preparedness and response [27,28].

6.1 Monitoring

Earthquake monitoring in Nigeria is carried by the Centre for Geodesy and Geodynamics Observatory in Toro. The other stations transmit data recorded to the seismic laboratory located in the center. Then the cumulative data is uploaded to the central server and IRIS.

6.2 Prediction

It is seemingly impossible to determine the exact location, time, magnitude and intensity of an earthquake that is yet to happen. However, researches are ongoing towards predicting future occurrence. There are couples of journals published with respect to the forecasting and prediction of earthquake in Nigeria using different techniques. In one of the publications, Wuyep et al. [2] reported that Geo-chemical techniques such as the use of radon, mercury and hydrogen can be used to forecast earthquakes in Nigeria.

A research by Oluwafemi et al. [3] reveals that Nigeria is at the risk of experiencing earthquake magnitudes as high as 6.0 in the year 2020; 6.5 between the year 2021 and 2022; 7.0 between the year 2025 and 2026 and 7.1 in the year 2028 with a 36.79% probability. The probability that an earthquake of magnitude 7.1 will be experienced from 2019 to 2028 also ranges from 9% to 36.79%.

6.3 Early Warning

Real-time seismic data availability and analysis can be used to warn the population about an impending earthquakes. This will assist in disaster management in the country. As part of its contribution to Research and Development, the National Space Research and Development Agency has designed an earthquake early warning system through one of its activity centers, the Centre for Geodesy and Geodynamics Toro, Bauchi State which will soon be launched by the Federal Government. The project called National Earthquake Response Scheme (NERS) is to be coordinated in collaboration with some relevant agencies, ministries, states and international bodies. The system is aimed at providing reliable, accurate, effective characterization of the shaking and near real-time ground motion and loss estimates following an earthquake.

The National Earthquake Warning System (NERS) will been established by the Centre for Geodesy and Geodynamics (CGG), as the first early warning and seismic risk mitigation system for the Nigeria. The central components of the system are expected to incorporate earthquake prediction algorithm, early warning to Nigerian citizens, data exchange, timely information dissemination and response. To put it succinctly, the warning system will provide notice before disaster strikes; thus, facilitating life safety and rapid hazard mitigation actions. When fully operational, the system will benefit the nation in effective loss prevention rules and methods, higher understanding of seismic processes, better engineering design, more effective hazard mitigation techniques, and improved disaster response and recovery.

6.4 Safety Tips

Since earthquake can't be control, it is only right to be equipped with the necessary safety tips for survival. Laishram [5] gave some safety tips in three stages:

6.4.1 Before an earthquake

i. Learn first aid, be prepared to act.
ii. Stock up on emergency supplies.
iii. Arrange your work area for safety.

6.4.2 During an earthquake

i. Remain calm as the quake occurs.
ii. Don't use elevators.
iii. Drop down; take cover under a desk or table and hold on.

6.4.3 After an earthquake

i. Remain calm and reassuring.
ii. Ready to act without electricity or lights.
iii. If you must leave a building, use extreme caution
iv. Use telephones only to report a life-threatening emergency.

7. CONCLUSION

Understanding earthquakes and the potential risks they pose is crucial for individuals and communities to be prepared and able to respond effectively in the event of an earthquake. While Nigeria's seismic activity is relatively moderate compared to some other regions, it is important to continue studying and monitoring earthquakes in the country to enhance preparedness and response strategies. Ongoing research, improved seismic monitoring networks, and collaboration with international institutions can contribute to a better understanding of earthquakes in Nigeria and facilitate effective mitigation efforts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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