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EARTH TREMORS - EMERGING THREATS IN NORTHERN NIGERIA

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ABSTRACT
The August 2000 Jushi Kwari, September 2016 Kwoi Kaduna, and September 2018 Mpape (Abuja) seismic events have clearly placed Nigeria's Northern states at high risk of earth tremors. Although the Northern part of Nigeria is far from earthquake-prone zones around the world, recent seismic activity in the region suggests that Northern Nigeria is now vulnerable to earthquakes. As a result, the purpose of this research is to identify the vulnerability and assess the evolution of tremor activities in Nigeria's Northern States. Previous research has revealed dominant NE-SW and NW-SE trending structures distributed throughout Northern Nigeria, with all major regional fault lines (Romanche, Chain Charlot, and St Paul) extending from the Atlantic Ocean linked to NE-SW and SW faults, which are interpreted as conduits of seismic energy that cause earth tremors in Nigeria.

Keywords: Earth tremors, seismic activities, northern Nigeria

INTRODUCTION

Earth tremors are small earthquakes that occur in the earth's crust. They are frequently described as minor earthquakes with magnitudes ranging from 1 to 4.5 on the Richter scale. It could also be a sudden release of energy caused by rock fracture and movement - along a fault. Most tremors occur along fault lines, such as the Saint Andreas fault in California, the East African Rifting System, and so on, or when two tectonic plates slide past each other. Seismic waves are generated by these processes and travel in all directions from the point of initial rupture (NGSA, 2018). Tremor tends to be concentrated in specific zones that coincide with the tectonic plate boundaries--convergent, divergent, and transform (Burke, 1971).

The orientation of zones of weakness in relation to the ambient stress field may be an important factor in determining which fault is likely to cause future earthquakes. Chandra was born in 1977.Many studies on tectonic maps/activities in Nigeria (Eluyemi and Saurabh, 2016) detailed a series of fracture and fault lines traversing a number of Northern Nigerian states: Kaduna, Kano Zamfara, Bauchi, Taraba, Adamawa, Gombe, Kogi, Benue, Plateau, Nasarawa, and Niger states, including the Federal Capital Territory of Abuja. He goes on to describe the severity of tectonism in accordance with Pan African orogeny, which accounts for persistent tremor throughout Nigeria's Northern state. Wright (1976) stated in his work on the fracture system in Nigeria that faulting in Nigeria extends to the West African Coast and coincides with landwards projection of the Romanche and chain fracture zones in the Atlantics. He also added in his contribution that the Dahomeyan Basin is bounded by the Romanche fracture zone to the west and the chain fracture zone to the east. The tremor was attributed by Onuoha (1989) to partial reactivation of plate boundaries.

In their study titled: probabilistic seismic hazard analysis of Nigeria Oluwafemi et al, (2018),they forecasted earthquakes in the future with the probabilistic magnitude of ratio 6.0 in year 2020 – 6.5 between 2021 and 2022; 7.0 between the year 2025 and 2026 and 7.1 in the year 2028 respectively (Kadiri et al., 2018). In their statistical and probabilistic seismic hazard assessment (Kadiri et al., 2018). investigated the trend of earthquake occurrence and reoccurrences parameters along the Mid-Atlantic ridge in West Africa region, they revealed seismic activities along Mid Atlantic Ridge are tectonic in nature and occurrences of larger magnitude earthquake are likely going to be on the increase in future. The occurrence of earth tremor in Yola and Gembu areas in North Eastern part of the country might be related to the seismic activities that occurred around Cameroon Mountain. The 1985 event in Komani Yaya could be attributed to the strike – slip Kaltungo fault, (Ugoduluwa et al., (1986).

It was once thought that Nigeria was completely free of seismic activity; however, tremor activities in previous years were not recorded by seismic instruments due to inadequate tools at the time of the occurrence. Taking into account seismic activity in Nigeria, studies show that future occurrences along fault lines in Nigeria are possible. Several earth tremors have been recorded over the years, with the majority of seismic activity occurring in Northern Nigeria's Central Zone.

Geology

The study area is part of the Northern Nigerian basement complex (see figure 1). The belt is thought to have evolved through plate tectonic processes caused by continental cohesion between the passive continental margin of the Tuaraep shield (Burke and Deway, (1972); Black, 1980; Ajibade et al, (1987), Rahaman, (1981: 1988). The study area is underlain by (Meta sedimentary rocks (migmatite gneiss schist and quartzites), which form the major basement complex rocks as defined by Oyawoye (1972), Mc Cury (1976), Woakes et al, (1987), and Rahaman (1976: 1988). Granites are well exposed in out crops, whereas meta sedimentary rocks are mostly exposed in road cuts and quarries. The crystalline rocks of the study area have been subjected to various degrees of deformation over the course of geological time, ranging from Precambrian to PanAfrican.

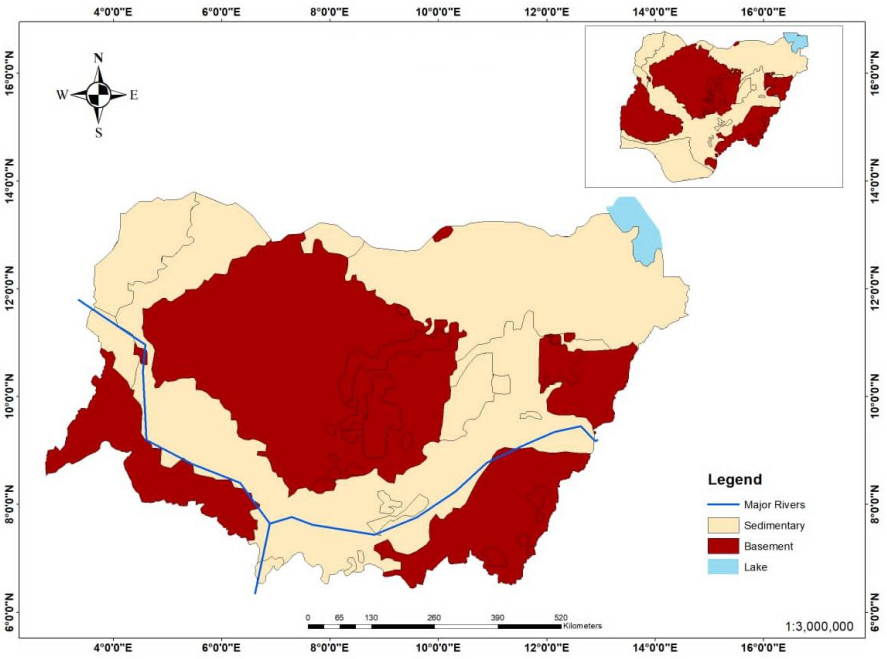

Figure 1: Geologic Map of Northern Nigeria showing the basement complex

Seismic Activities in Northern Nigeria

Seismicity describes the frequency and intensity of earthquakes (tremor) in a region Papazaches (2003) or the region's susceptibility to earthquake occurrence (historical past and expected future) Rao and Rao (2004). According to seismic experts, recent and repeated tremors in Northern Nigeria of low to medium magnitude serve as a precursor to a massive and potentially disastrous earthquake in the near future, as these tremors fail to release the majority of the stress that accumulates within fault rupture zones. Bolt, (2005). Northern Nigeria has experienced approximately 17 tremor activities over the last 43 years fig 2.

One such event was a tremor reported on March 25, 2006 in a remote Lumpa resettlement near Minna, Niger State, Northern Nigeria. The tremor event causes panic, and farm workers are forced to flee for safety. It documents some degree of damage with cracks on the wall.

Table 1: List of Historical Earth Tremors in Northern Nigeria

S/No	Date	Time	Felt Area	State	Intensity	Probable Epic Centre	Remarks
1	1982		Jalingo	Taraba	III	Close to Cameroun	11.3771°E 8.8929° N,
2	1984		Yola	Adamawa	III	Close to Cameroun U. Line	12.4782°E 9.2095° N,
3	1985	21:00	Kambari Yaya	Bauchi	V	Kambari Yaya	Surface fracture $11^0$0'E $10^0$02'N
4	1986	10:45	Obi	Benue	III	Close to Obi	$08^0$46'E $08^0$22'N
5	1975		Dambata	Kano			$08^0$31'E 12^0 2'N
6	1987		Gembu	Taraba	V	Close to Cameroun	$11^0$15'E $06^0$42'N
7	1987		Akko	Gombe	IV	Close to Akko	$10^0$57'E $10^0$17'N
8	1987		Kurba	Bauchi	III	Close to Kurba Village	$10^0$12'E $11^0$29'N
9	1988	05:07:51	Oserurun Hill	Gombe			11°10′02″E 10°17′22″ N
10	1994		Dan Guibi	Adamawa	III	Dan Guibi	12.4984°E 9.5265° N,
11	1990		Jere	Kaduna	V		7.4354° E 9.5684° N
12	2000		Jushi Kwari	Kaduna	III	Close to Jushi Kwari Village	$07^0$42'E $14^0$03'N
13	2006	11:20	Lumpa	Niger	III	Close to Ifewan Fault zone, Zungeru	6.4167E 9.2833N
14	2016	11:20	Sambang Daji	Kaduna	III		8.08905°E 9.46482°N
15	2005		Yola	Adamawa	III	Dan Guibi	12.3984°E 9.4265° N,
16	2018		Mpape	Abuja	II – IV		7.50° E 9.15° N
17	2018	2:30	Jahi – Gwarinpa	Abuja	II	Mpape	$7^0$50'E $9^0$32'N

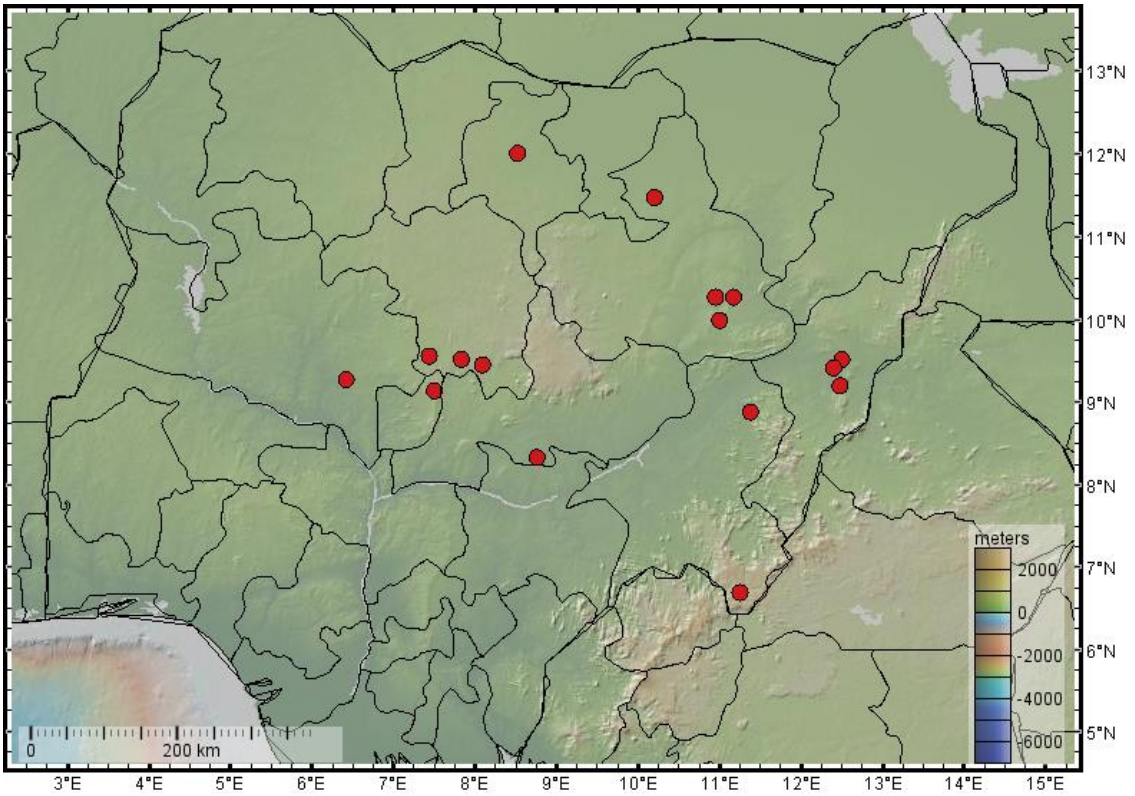

Figure 2: Map showing events (Red balls) in the Northern part of Nigeria.

Table 2: Location of Current and Proposed Seismic Station in Northern Nigeria.

S/No	Station Code	Name	Geological formation	Instrument installed	Coordinates	
					Latitude	Longitude
1	ABJ.	Abuja	Granite	No instrument installed	$08^{0}59'$ 126'N	$07^{0}23'$ 338'E
2	KAD	Kaduna	Granite	EP – 105 Broadband seismometer DR4000 recorder	10'26'101'N	$07^{0}38484'$E
3	MNA	Minna	Granite Gneiss	6TD; T36351/2777-120s-100Hz Digital Guralp Sensor	$09^{0}30'702'$N	$06^{0}26'411'$E
4	TOR		Granite	3ESPCD120 S-100HZ Digital Guralp Sensor	10°03.303′	09°07.089′

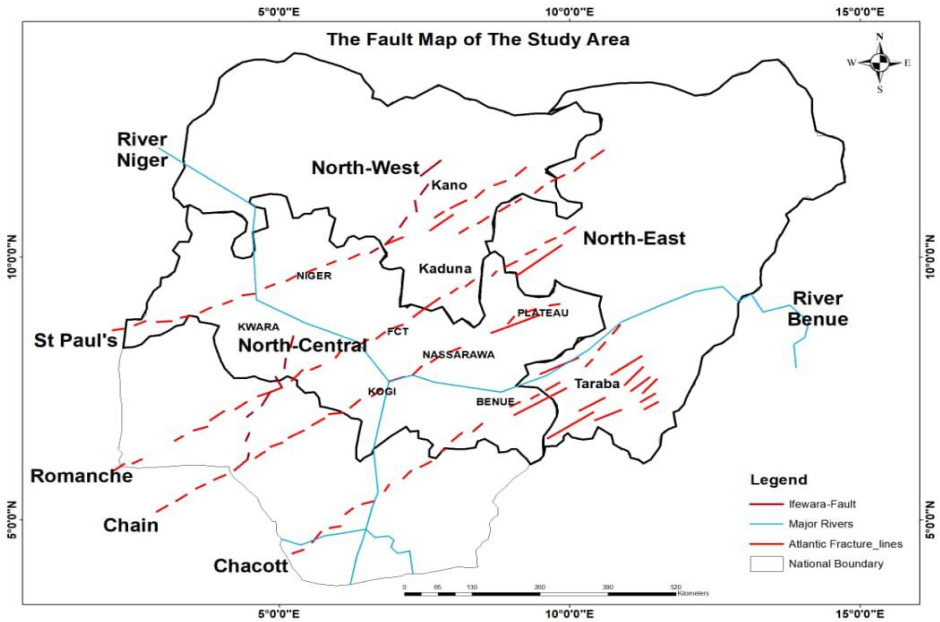

Figure 3: Map of Nigerian showing fault lines traversing all the Northern States that have experienced seismic activities

MATERIAL AND METHODS

The parametric earthquake data used in these studies was obtained from the Nigerian National Network of Seismographic Stations (NNNSS). Other data sources used include secondary sources and reports from previous studies on the subject. The downloaded geological satellite map of Nigeria from the FAO was geo-referenced to (UTM 1984), and all areas of interest were highlighted and clipped out. All subsurface structures were accessed using Spot 5 and ArcMap software version 10.8, and ground photographs of some surface fault lines were also collected, as shown in Plates 1 and 2.

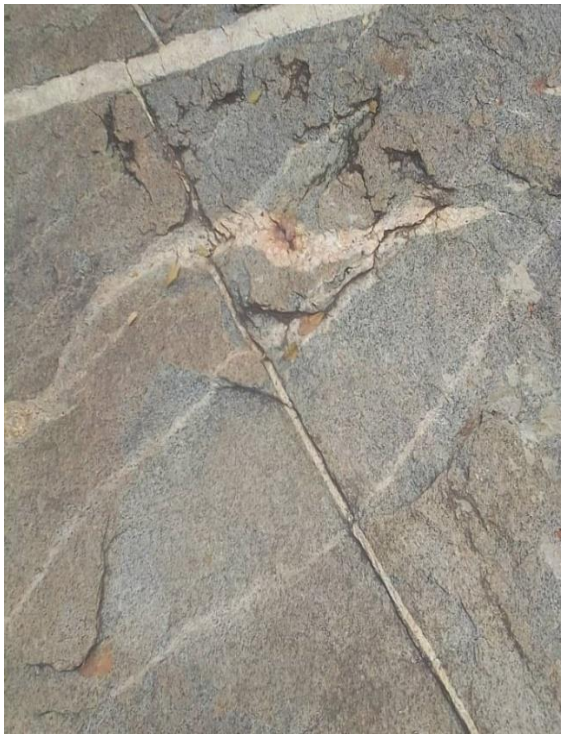

Plate 1: Quartzo-feldspartic veins/fault Line in Lokoja, Kogi State

Plate 2: Regional Faults observed in Jahi, Abuja

RESULTS AND DISCUSSION

As reported by (Ajakaiye et al, 1984), the causes of earth tremors in Northern Nigeria have been attributed to a NE - SW trending fracture zone of weakness extending from the Atlantic Ocean into the country. Microseismic studies of the Northern part of Nigeria indicate that seismic activities are associated with the active faulting of the Mid Atlantic Ridge transform fracture zone (Romanche, Chain, Charcot, and St. Paul fracture zone), as shown in figure3. It is thought to be part of the Pelusiummegashear system that runs across Africa (Neeve and Hall, 1982). These transform fracture zones run through all of Northern Nigeria's major states.

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Edward (2008), Ofonime and Tahir (2010), Kadiri et al, (2014) and Muhammed et al, (2015), in their finding reported the following states /localities are under the influence of the extensive fracture / fault line emanating from the Gulf of Guinea. Kaduna, Kano and Zamfara in the North – West, Jigawa, Bauchi, Taraba, Adamawa and Gombe North – East and also Kwara, Abuja, Benue, Kogi, Plateau, Nasarawa and Niger all in the North-Central Nigeria.

The regional fault system and the longest linear fracture Ifewara - Zungeru fault within Nigeria's Pre-Cambrian basement complex are linked to the possible origin of seismicity in Northern Nigeria and the spatial distribution of tremor within the zone. These fault lines extend from south of Lafiagi in Kwara State to Zungeru in Niger State and beyond to Calangai in Northern Nigeria, according to Anifowose et al. (2006).

Table 3: Occurrences of seismic activities in some Northern Nigerian States

S/N	North-West (NW)	Frequency	North – East	(NE)	North-Central (NC)	Frequency
1	Zamfara	1	Adamawa	2	Abuja	2
2	Kano	1	Bauchi	2	Benue	1
3	Kaduna	4	Gombe	2	Niger	1
4			Taraba	2		
	Total	**6**		**8**		**4**

Table 3: Shows seven town within four of the North – East with tremor of various degree of intensities, which occurred within the period of 1982 – 2005; making the zone the worst hit in the Northern region. The North – West reported about 6 events with an upward progression in the year 2000 to 2016 around Jushi, Kwari, Sanbang Daji with Kwoi in Kaduna State. The North-Central states of Benue, Niger and Abuja (Mpape) also experienced some seismic activities, Fig. 4 and table 4 respectively.

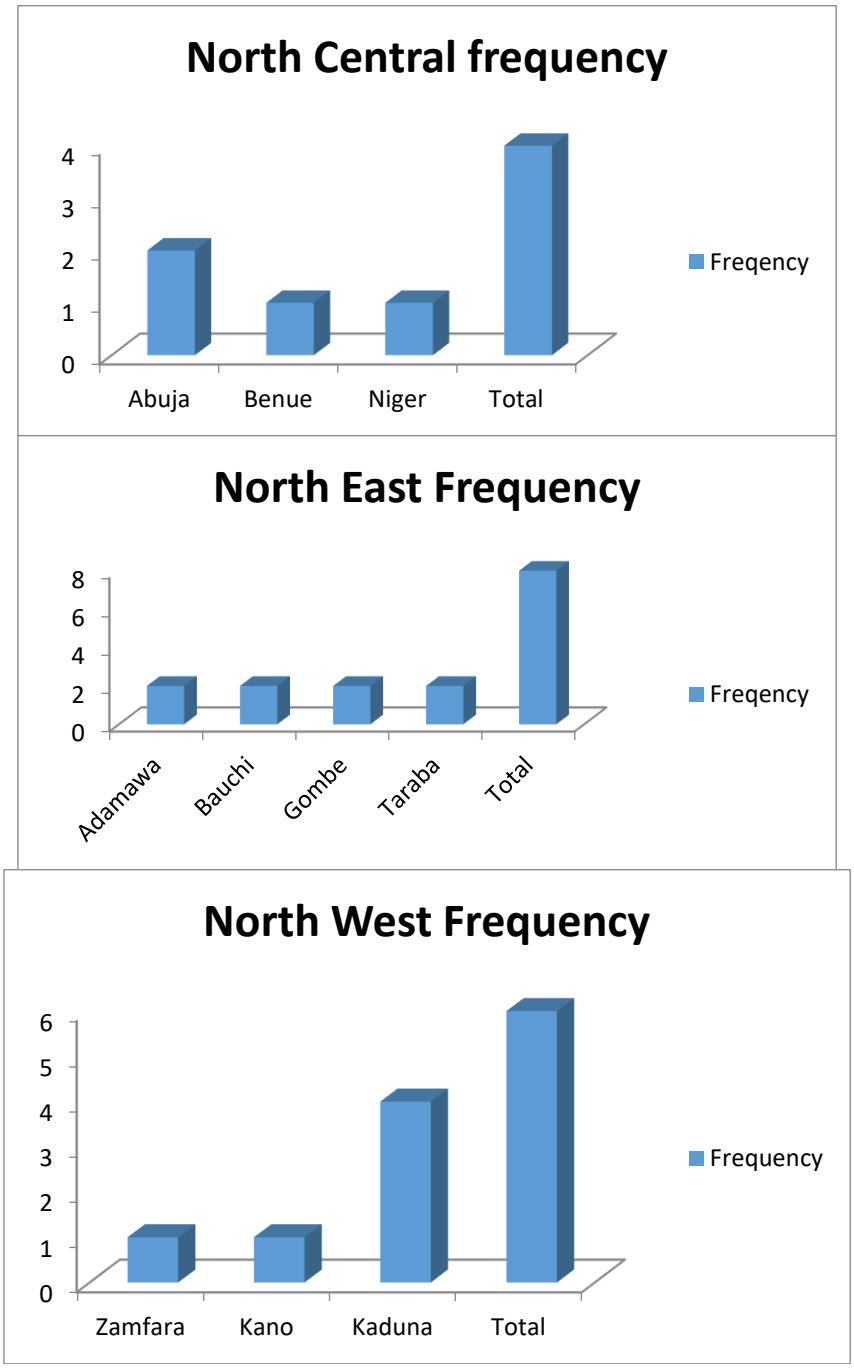

Figure 4: Statistical Spread of Seismic Activities in Northern Nigeria

Analysis of Tremor events in Northern Nigeria within the last 28 years

Table 4: North-Western Tremor

S/N	Year	Town	State
1	1974	Dan Guibi	Zamfara
2	1975	Dambata	Kano
3	1990	Jere	Kaduna
4	2000	Jushi Kwari	Kaduna
5	2016	Kwoi	Kaduna
6	2016	Sambang Daji	Kaduna

The first in Nigeria's North-Western region was the Dan Guibi in Zamfara State in 1974, followed by the Kano event in Dambata 1975, with a dramatic increase in seismic activity along Kaduna in Jere 1990 and the Dushi-Kwari activities in 2005, followed by the Kwoi event in 2016, which rattled many objects and houses.

The trend in the North-East Zone was sequential between Jalingo in Taraba State in 1982 and Yola in Adamawa State in 2005, whereas the North-Central Zone had three (3) major tremor occurrences between Obi in Benue State in 1986 and Lumpa in Niger State in 2006, followed by the Mpape event in 2018. Tables 4 - 6 show the increase in tremor activity in Northern Nigeria over the last 43 years. The zone's fourth lines are becoming increasingly active.

Table 5: North – Eastern Tremor

S/N	Year	Town	State
1	1982	Jalingo	Taraba
2	1984	Yola	Adamawa
3	1985	Kambair	Bauchi
4	1987	Gembu	Taraba
5	1987	Akko	Bauchi
6	1987	Kurba	Bauchi
7	1988	Oserunm	Gombe
8	2005	Yola	Adamawa

Table 6: North – Central Tremor

S/N	Year	Town	State
1	1986	Obi	Benue
2	2006	Lumpa	Niger
3	2018	Mpape	Abuja FCT

CONCLUSION

Northern Nigeria is gradually transiting into active zone for earth tremor activities as against the earlier belief about the region being aseismic. Fault lines within the northern country are becoming reactivated and clearly associated with most epicenters of earth tremors in the zone. Nigeria and the Northern region of the country in particular, is not only prone to seismic activities, but the frequency of occurrence is on the increase. The recent 2018 Mpape events is another pointer to the increasing occurrence of seismic activities in the region. To date, the Northern part of the country has recorded about 17 events, table 1, with the North-East leading with 8 occurrences, followed by the North-West with 6, and the North-Central, which was previously thought to be stable, has recorded a total of about 3 events with the recent Mpape tremor. As a result of the aforementioned, It is convenient to state that all of the regional fault lines (St. Paul, Romanche, Chair, and Charcot) as well as the Ifewara-Zungeru mega-sharing zone that traverses the South-Western to Northern-Western Nigeria etc., are gradually becoming active. and proactive measures are highly encouraged at this juncture to avoid any potential negative consequences of seismic activities that may arise in Northern Nigeria in the future. Earthquakes are unavoidable. However, much can be done to prevent their catastrophic impacts; it is high time to be much more concerned about the impending earthquakes in order to avoid excessive loss of lives and property in the national interest. The following are suggested short-term measures: short – time frame Seismological stations should be established near tremor-prone areas, and a number of short-period sensors should be acquired for routine campaigns, and there is a need to upgrade existing seismological stations and expand the network for effective national coverage by acquiring and installing more seismometers, densifying seismic equipment; co-locate them with GPS receivers and magneto-meters for long-term continuous monitoring of microseismic activities in areas that are prone to earth tremors.

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