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***Review Article***

# A Minireview of Seismicity in North Central Nigeria and Implications for Seismic Hazard Assessment

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**ABSTRACT**
Recent low-to-intermediate magnitude earthquakes in North Central Nigeria, particularly around Kwoi in Southern Kaduna and Abuja region, have challenged the historical perception of the country as a seismically stable region. This minireview synthesizes current knowledge on this emerging seismic activity, its tectonic controls, and its implications for hazard assessment. The seismicity is fundamentally linked to NE-SW and NW-SW trending fault systems, such as extensions of the North Atlantic Romanche fault, which facilitate stress release within the region's complex basement terrain. The establishment of national seismic networks has enabled better characterization of these events. Probabilistic Seismic Hazard Analysis (PSHA) indicates Nigeria faces a non-negligible risk, with estimates suggesting potential for magnitudes up to 7.1. Peak Ground Acceleration (PGA) values show significant spatial variation, with major urban centers like Lagos facing higher hazards. The review underscores critical gaps, including the lack of region-specific Ground Motion Prediction Equations (GMPEs) and the need for detailed fault characterization. It concludes that comprehensive seismic hazard assessment, integrating geophysical data with seismic monitoring, is imperative for infrastructure resilience, building code development, and disaster preparedness in this newly recognized seismic zone.

**Keywords:** GMPEs; Hazard; Kwoi; PGA; PSHA; Resilience; Seismicity

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## INTRODUCTION

Northcentral Nigeria, particularly Kwoi area of Southern Kaduna and Abuja region, as well as the surrounding areas, has emerged as an important zone of seismic activity despite the country's historical classification as a relatively aseismic region. Over the past two decades, several low- to intermediate-magnitude earthquakes have been recorded within and around the Abuja region, providing crucial opportunities to understand the tectonic processes and seismic characteristics of the area (Ologe *et al*., 2023). These seismic occurrences have transformed our understanding of Nigeria's geotectonic setting and necessitate a comprehensive seismic hazard assessment for infrastructure protection and disaster preparedness. The paradigm of continental seismicity is evolving, with stable cratonic interiors no longer viewed as permanently aseismic. A compelling illustration of this global reassessment is emerging from West Africa, where Nigeria—historically classified as a low-seismicity, stable continental region within the West African Craton—has recorded a disquieting sequence of low-to-moderate magnitude earthquakes in its north-central region over the past two decades (Adepelumi *et al*., 2011; Ologe *et al*., 2023). Notable events, including the 2018 Mpape (Abuja) tremor, have starkly contradicted long-held assumptions and exposed a critical knowledge gap in the regional tectono-seismic framework (Oyibo & Kadiri, 2023). This emergent seismicity is not merely an academic curiosity; it poses a tangible and escalating risk to Nigeria's

rapidly developing infrastructure, densely populated urban centers like Abuja, and proposed critical facilities, thereby transforming seismic hazard assessment from a theoretical exercise into an urgent national imperative (Molua *et al*., 2024).

The drivers of this intraplate seismicity are enigmatic, as they occur far from active plate boundaries. Contemporary research implicates the reactivation of pre-existing, deep-seated basement structures under the influence of contemporary stress fields. High-resolution aeromagnetic data have been pivotal in mapping these structures, revealing dominant NE-SW and NW-SE trending lineaments that correlate strongly with recent epicenters (David *et al*., 2022). Furthermore, evidence suggests a potential geodynamic influence, with lithospheric thinning in the north-central region possibly linked to distal plume effects, adding a layer of complexity to the hazard profile (Lawal *et al*., 2025). This tectonic reawakening necessitates a move beyond qualitative descriptions to a quantitative, probabilistic framework for risk estimation. However, seismic hazard assessment in Nigeria remains fundamentally constrained by the brevity of the instrumental catalog, the absence of region-specific ground-motion prediction equations (GMPEs), and an incomplete characterization of active fault geometries and slip rates (Eluyemi *et al*., 2020; Teibo *et al*., 2018).

Consequently, existing probabilistic seismic hazard analyses (PSHAs) often rely on imported attenuation models, potentially misrepresenting the true ground-shaking potential for Nigerian bedrock and site conditions. Initial PSHA results are sobering, indicating non-negligible probabilities for significant future earthquakes and revealing high Peak Ground Acceleration (PGA) values in key urban areas (Oluwafemi *et al*., 2018). Therefore, a synthesized understanding that integrates seismological records, geophysical delineation of fault systems, and robust hazard modeling is critically lacking. This minireview aims to bridge this gap by consolidating current knowledge on the seismicity of north-central Nigeria. This work provides a consolidated foundation to steer future research and inform evidence-based risk mitigation strategies in a region of newly recognized seismic vulnerability.

## SEISMIC BACKGROUND AND RECENT ACTIVITY

The recorded seismic activity in northcentral Nigeria presents a significant shift from the traditional perception of the region as tectonically quiet. Significant tremor events have been documented in recent years, including the August 2000 Jushi Kwari event, September 2016 Kwoi Kaduna occurrence, and notably the September 2018 Mpape (Abuja) seismic event (Oyibo & Kadiri, 2023). These earth tremor, though generally of low to intermediate magnitudes, indicate active crustal deformation processes that warrant detailed investigation and systematic monitoring.

The establishment of seismic monitoring networks has been instrumental in characterizing this seismicity. In October 2018, the Federal Government of Nigeria established several seismic stations in different locations across the country, with three of these strategic stations located in the Abuja region (the Federal Capital Territory) and managed by the Nigerian Geological Survey Agency (Ologe *et al*., 2023). These monitoring facilities have generated valuable datasets that enable detailed spectral analysis and background noise characterization, essential for understanding the local seismic environment and improving hazard estimations.

## STRUCTURAL AND TECTONIC FRAMEWORK

The seismicity in northcentral Nigeria is fundamentally controlled by complex fault systems and lineament structures that reflect the region's complex tectonic history. Detailed aeromagnetic investigations have revealed that dominant structural trends in northcentral Nigeria are oriented in NE-SW and NW-SE directions, with these lineaments distributed throughout the region and serving as critical conduits for seismic energy transmission (David *et al*., 2022). The NE-SW trending structures are particularly significant, as they correspond to major lithospheric processes and fracture lines that cross-cut the underlying geological formations.

The tectonic framework of northcentral Nigeria is influenced by several regional fault systems linked to major Atlantic fracture zones. The regional North Atlantic Romanche fault system, which extends offshore through the Niger Delta into the continental crust, has been traced and thought to extend through the Gwagwalada area southward through Gwarinpa and Mpape, extending beyond Kafanchan (David *et al*., 2022). These major fault systems act as crucial pathways for stress release and seismic energy dissipation. The integration of Shuttle Radar Topographic Mission (SRTM) data with aeromagnetic datasets has demonstrated that most tremor epicenters occur near elevated terrains, where topographic loading and structural complexity enhance seismic susceptibility (Lawal *et al*., 2025).

Recent investigations have revealed that the areas prone to earthquake activity in north-central Nigeria are directly linked by numerous faults that serve as conduits for seismic energy transmission. The highly deformed nature of the basement complex in these regions creates an environment conducive to tremor generation through stress accumulation and release along pre-existing fault planes (David *et al*., 2022). Furthermore, Curie Point Depth (CPD) estimates have highlighted lithospheric thinning in the northcentral region (approximately 1.6-13 km), likely influenced by plume dynamics associated with the St. Helena hotspot, in contrast to deeper CPD values (7.2-13 km) in the southwest (Lawal *et al*., 2025).

## SEISMIC HAZARD CHARACTERISTICS

The probabilistic seismic hazard analysis framework applied to Nigeria provides crucial insights into future earthquake risks. Research has established that Nigeria faces the risk of experiencing earthquake magnitudes as high as 6.0 in the year 2020, 6.5 between 2021 and 2022, 7.0 between 2025 and 2026, and 7.1 in the year 2028 with a 36.79% probability (Oluwafemi *et al*., 2018). These estimates, derived through the application of the Gutenberg-Richter recurrence law, indicate that Nigeria's seismic hazard extends beyond traditional expectations and necessitates comprehensive preparedness strategies. For urban centers specifically, seismic hazard assessments have demonstrated high seismic hazard levels in major cities. Peak Ground Acceleration values show significant spatial variation, with Lagos experiencing PGA values around 0.432g, considerably higher than lower-risk areas such as Maiduguri (0.143g) (Molua *et al*., 2024). The susceptibility analysis discovered that steel frame structures (77.74%) and precast concrete (71.13%) are most likely affected by seismic disturbances among common construction materials, highlighting the importance of building code compliance and structural resilience in seismic design.

## METHODOLOGICAL APPROACHES TO HAZARD ASSESSMENT

Probabilistic seismic hazard analysis (PSHA) represents the primary framework for systematic assessment of earthquake risks in northcentral Nigeria. The methodology involves defining seismic source models, characterizing seismicity parameters including recurrence relationships, and integrating ground motion prediction equations with local site conditions (Teibo *et al*., 2018). For southwestern Nigeria specifically, PSHA studies have established that the region likely experiences magnitude earthquakes as high as 7.2 by the year 2028 with a 36.79% probability, emphasizing the need for continuous monitoring and regular hazard reassessment (Teibo *et al*., 2018).

The implementation of PSHA in Nigerian contexts requires careful consideration of catalog completeness, as instrumental earthquake records in the country are relatively recent. Ground motion modeling using synthetic seismogram generation, based on stochastic approaches, has proven useful for predicting expected peak velocity and acceleration values in study areas where direct strong-motion recordings are limited (Adepelumi *et al*., 2011). The estimated peak ground accelerations in southwestern Nigeria, ranging from 0.16 to 0.69g, demonstrate the necessity of incorporating these estimates into regional building code development and infrastructure design standards.

## SITE-SPECIFIC INVESTIGATIONS

Beyond regional assessments, site-specific seismic hazard evaluations represent an essential component of comprehensive risk management. Subsurface characterization through integrated geophysical methods has revealed important information about local site effects and ground response to earthquake shaking. The integration of Vertical Electrical Sounding (VES) and seismic refraction data with lithological information provides crucial insights into the subsurface structure that influences ground motion amplification (George *et al*., 2025). Such investigations have identified zones with high potential for soil liquefaction and erosion during seismic events, particularly in areas with predominantly sandy deposits and highwater tables.

## IMPLICATIONS FOR SEISMIC HAZARD ASSESSMENT

The characterization of seismicity in northcentral Nigeria carries multiple implications for comprehensive seismic hazard assessment. First, the recognized seismic activity necessitates the development and implementation of regionally-specific ground motion prediction equations (GMPEs) tailored to the West African geological and seismotectonic context. Current probabilistic seismic hazard analysis frameworks often rely on foreign GMPEs that may not accurately capture the specific characteristics of crustal attenuation and site response in the Nigerian environment (Eluyemi *et al*., 2020).

Second, the integration of multiple data sources, including historical earthquake records, instrumental seismicity data, aeromagnetic interpretation, and geodetic measurements, provides a more robust foundation for seismic hazard modeling. The combination of geophysical techniques with seismic data has proven effective in identifying and characterizing fault systems that control seismic activity (Ike *et al*., 2024). For instance, the identification of buried faults through high-resolution aeromagnetic data interpretation has revealed deep tectonic fault features with estimated depths ranging from approximately 200 meters to 2500 meters, with fault trends predominantly in the NE-SW direction, suggesting connection to regional fault zones (Aluko *et al*., 2025).

Third, nuclear installations and critical infrastructure sites require particularly rigorous seismic hazard assessment. The evaluation of seismicity indices for nuclear installations has resulted in the computation of a b-value of 0.43 for Nigeria, which quantitatively measures the seismic hazard or risk of the region (Lawal *et al*., 2024). This parameter, derived from the fractal dimension of the network of recorded tremor event locations and fault traces mapped from aeromagnetic data, provides crucial input for establishing the International Atomic Energy Agency safety guidelines for nuclear facility siting.

## CONCLUSION AND FUTURE RESEARCH DIRECTIONS

The recognition of active seismicity in northcentral Nigeria represents a fundamental shift in understanding the country's tectonic setting and earthquake risk. The documented occurrence of earthquakes in this region, previously considered aseismic, demonstrates the necessity for continuous seismic monitoring and hazard assessment. Future research should prioritize: the development of Nigeria-specific GMPEs based on regional seismic data; improved characterization of active fault geometries and recurrence intervals; integration of paleoseismic evidence with instrumental records to extend the temporal framework for hazard estimation; and site-specific investigations for critical infrastructure respectively, The implications of recognized seismicity in northcentral Nigeria extend beyond academic interest to directly affect infrastructure planning, building code development, and disaster preparedness strategies.

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