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# GEOPHYSICAL ANALYSIS OF MINING-INDUCED SEISMICITY ASSOCIATED WITH ARTISANAL TIN MINING IN JOS PLATEAU AND GOLD MINING IN ZAMFARA STATE, NIGERIA

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**Abstract**
The research investigated the geophysical properties and effects of mining-induced seismicity linked to artisanal mining operations in the Jos Plateau and Zamfara State. The objectives are to determine the spatial and temporal distribution of seismic events in relation to active artisanal mining sites in Jos Plateau and Zamfara State, compare the seismic characteristics associated with tin mining in Jos Plateau and gold mining in Zamfara State and examine the environmental and socio-economic impacts of mining-induced seismicity on communities surrounding the study areas. The study adopted a quantitative geophysical research design. The study relies on both primary and secondary data sources. The instruments for data collecting are GPS mapping, questionnaires, and interview guides. Sampling approaches utilised spatial data gathered via GPS readings of mining sites to determine their precise positions and facilitate spatial linkage with seismic events. Data from questionnaires and interviews are gathered using structured instruments delivered to inhabitants. Data analysis was carried out using Geographic Information System software and the frequency distribution of seismic events over time. The analysis confirms that seismic events in the study areas are spatially concentrated around mining zones, temporally associated with periods of increased mining activity, and vary in characteristics depending on geological and operational conditions. The study recommended that the Federal government of Nigeria should establish a permanent seismic monitoring station in major artisanal mining regions, particularly in Jos Plateau and Zamfara State, to enable real-time detection and recording of seismic events.

**Keywords:** Seismic, artisanal mining, earth tremors, earthquake, geophysical.

## 1.0 Introduction

Seismic events, including ground tremors and low-magnitude earthquakes, have conventionally been linked to natural tectonic processes. However, recent studies show that human activities, particularly mining, can induce seismic events. This phenomenon, known as mining-induced seismicity, has been increasingly documented in regions with intensive underground and artisanal mining operations. Activities such as drilling, blasting, excavation, and subsurface material extraction can significantly alter stress conditions within the Earth's crust, thereby triggering seismic disturbances (Foulger *et al.*, 2020; United States Geological Survey, 2023).

In Nigeria, artisanal and small-scale mining has expanded rapidly in recent years, particularly in mineral-rich regions such as the Jos Plateau and Zamfara State. The Jos Plateau has long been associated with tin mining, while Zamfara State is notable for gold mining activities. These operations are frequently informal and inadequately controlled, with insufficient geophysical monitoring systems established. This situation increases the risk of environmental degradation and geohazards, including ground instability and possible seismic occurrences (World Bank, 2020; United Nations Environment Programme, 2022).

Nigerian Geological Survey Agency reports have indicated the occurrence of earthquakes in different parts of Nigeria, raising concerns about their possible linkage to anthropogenic activities such as mining. However, there remains a lack of comprehensive geophysical investigations that clearly establish the spatial and temporal relationship between seismic events and artisanal mining operations. Understanding these patterns is essential in determining whether such tremors are naturally occurring or induced by mining activities (Nigerian Geological Survey Agency, 2022).

Moreover, disparities in geological contexts and extraction techniques between tin mining in the Jos Plateau and gold mining in Zamfara State may lead to changes in seismic attributes such as magnitude, frequency, and waveform behaviour. Comparative analysis of these regions is therefore important for identifying the underlying mechanisms influencing mining-induced seismicity (International Seismological Centre, 2023).

Beyond geophysical considerations, mining-induced seismicity poses potential environmental and socio-economic risks to surrounding communities. Ground vibrations can damage infrastructure, while uncertainty and fear associated with tremors may disrupt livelihoods and social stability. In regions already facing economic and environmental challenges, these impacts can be particularly severe (International Labour Organization, 2021).

This study is therefore motivated by the need to investigate mining-induced seismicity in Nigeria by focusing on the spatial and temporal distribution of seismic events, comparing seismic characteristics between key mining regions, and assessing the associated environmental and socio-economic impacts. The findings are expected to contribute to improved monitoring, risk management, and policy development for safer and more sustainable artisanal mining practices.

## 2. Statement of the Problem

From 2020 to 2026, there has been growing apprehension regarding the prevalence of earth tremors and low-magnitude seismic events in various regions of Nigeria. Although such events are frequently ascribed to natural tectonic processes, accumulating evidence indicates that human activities, notably mining, can produce seismicity. In areas such as the Jos Plateau and Zamfara State, where artisanal tin and gold mining is prevalent, the likelihood of mining-induced seismic occurrences remains largely unexamined (Nigerian Geological Survey Agency (2022).

Artisanal and small-scale mining in these regions is primarily informal, unregulated, and marked by rudimentary extraction methods include manual excavation, shallow tunnelling, and, in certain instances, indiscriminate blasting (United Nations Environment Programme 2022). These activities can significantly disturb subsurface geological structures, alter stress regimes, and potentially trigger localized seismic events. Despite these risks, there is a lack of systematic geophysical monitoring and data collection to accurately detect, record, and analyze seismic occurrences associated with mining operations in Nigeria.

Moreover, there is inadequate empirical information demonstrating the spatial and temporal correlation between seismic occurrences and active mining locations in the research regions (World Bank. (2020). Without this understanding, it is difficult to determine whether the observed tremors are naturally occurring or induced by mining activities. In addition, little is known about how seismic characteristics such as magnitude, frequency, and waveform patterns vary between tin mining activities in the Jos Plateau and gold mining operations in Zamfara State, given their differing geological settings and extraction methods.

Beyond the geophysical uncertainties, the potential environmental and socio-economic impacts of mining-induced seismicity on surrounding communities remain poorly documented. Residents in mining regions may face risks such as structural damage to buildings, land instability, and psychological stress associated with recurrent tremors. The absence of reliable data and risk assessment frameworks further exacerbates community vulnerability and limits the ability of policymakers to develop effective mitigation strategies. Therefore, the main problem this study addresses is the lack of comprehensive geophysical analysis linking artisanal mining activities to seismic events in Nigeria, particularly in the Jos Plateau and Zamfara State. This gap in knowledge hinders accurate risk assessment, informed decision-making, and the development of appropriate monitoring and regulatory frameworks for sustainable mining practices.

**3. Objectives of the Study**

To investigate the geophysical characteristics and impacts of mining-induced seismicity associated with artisanal mining activities in the Jos Plateau and Zamfara State. Specific Objectives are to:

1. determine the spatial and temporal distribution of seismic events in relation to active artisanal mining sites in Jos Plateau and Zamfara State.
2. compare the seismic characteristics (e.g., magnitude, frequency, and waveform signatures) associated with tin mining in Jos Plateau and gold mining in Zamfara State.
3. examine the environmental and socio-economic impacts of mining-induced seismicity on communities surrounding the study areas.

**4. Scope of the Study**

This study is delimited in terms of both geographical and temporal scope to ensure a focused and in-depth investigation of mining-induced seismicity in Nigeria. This study is limited to two principal artisanal mining regions in Nigeria: the Jos Plateau and Zamfara State. The Jos Plateau is a historically significant tin mining area known for extensive artisanal operations, whereas Zamfara State is noted for its prominence in artisanal gold mining. These regions are selected due to their active mining activities, unique geological characteristics, and documented instances of ground disturbances. The research will concentrate on specific mining communities within these areas where artisanal mining is most prevalent and where seismic activities are either suspected or have been documented.

The study covers a recent and relevant time frame, focusing on seismic events and mining activities within the period 2020 to 2025. This period is selected to capture contemporary trends in artisanal mining expansion and reported earth tremor occurrences in Nigeria. It also aligns with the availability of recent geophysical data, reports, and technological advancements in seismic monitoring. Where necessary, earlier data may be referenced to provide background context and support trend analysis.

## 5. Literature Review

### Conceptual Review

Mining-induced seismicity refers to seismic events that are triggered by anthropogenic activities, particularly mining operations that disturb the natural stress equilibrium of the Earth's crust. Unlike tectonic earthquakes, which result from long-term plate movements, mining-induced seismicity occurs due to abrupt stress redistribution caused by excavation, blasting, fluid extraction, or rock failure in underground or surface mines (Foulger et al., 2021).

Recent advances in geophysical research show that even small-scale mining activities can generate measurable seismic signals when they intersect pre-existing geological weaknesses such as faults, fractures, or shear zones. These disturbances may range from microseismic events (too small to be felt) to low-magnitude tremors capable of causing surface vibrations (Kaiser & Kim, 2021).

In the context of artisanal mining regions such as the Jos Plateau and Zamfara State, mining activities are often unregulated and involve shallow excavation, tunneling, and manual extraction methods. These practices increase the likelihood of localized ground instability and may contribute to stress redistribution within shallow crustal layers. According to UNEP (2022), artisanal mining environments are particularly vulnerable to geohazards due to the absence of engineering control, monitoring systems, and environmental regulation.

### Theoretical Review

The theoretical foundation of mining-induced seismicity is rooted in rock mechanics, elastic rebound theory, and stress transfer models. Rock mechanics explains how stress, strain, and failure interact in geological materials. When mining removes large volumes of rock, the surrounding material must adjust to new stress conditions. If the stress exceeds the rock strength, failure occurs in the form of fractures or seismic events (Gischig, 2020).

Elastic rebound theory further explains that accumulated strain energy in rocks is suddenly released when failure occurs along a fault or fracture plane. In mining environments, this process is accelerated by excavation activities that alter stress equilibrium.

Recent numerical models suggest that mining-induced seismicity is strongly influenced by:

i. Depth of excavation
ii. Rock mass quality
iii. Presence of pre-existing faults
iv. iv Rate of material extraction (Kaiser & Kim, 2021)

These factors are highly relevant in Nigerian mining regions, where geological formations consist of fractured basement complex rocks that are susceptible to stress redistribution.

### Mechanisms of Mining-Induced Seismicity

Mining-induced seismicity occurs through several geophysical mechanisms:

i. Stress Redistribution: When material is extracted, surrounding rocks experience increased stress concentration, leading to failure zones.
ii. Fault Reactivation: Pre-existing faults may be reactivated when mining alters

stress conditions, resulting in seismic slip events.

iii. Excavation Collapse: Shallow artisanal mining often leads to roof collapse in underground voids, producing localized tremors.

iv. Vibration from Blasting: Although less common in artisanal mining, uncontrolled blasting can generate seismic waves that propagate through surrounding rock masses.

These mechanisms are widely documented in global mining regions and are applicable to both tin mining in Jos Plateau and gold mining in Zamfara State.

**Empirical Review**

Empirical research on induced seismicity has expanded significantly over the past decade. Foulger et al., 2021) provided a global synthesis of anthropogenic earthquakes and confirmed that mining is one of the primary human activities capable of generating seismicity.

In deep-level mining environments, van Aswegen and Durrheim (2020) observed that seismic event frequency increases with mining depth and extraction intensity. Their study in South African gold mines demonstrated a strong correlation between excavation rate and seismic activity occurrence.

Similarly, Maxwell et al.,(2022) used microseismic monitoring systems to map seismic events in underground mines, showing that seismicity clusters around active excavation zones. Their findings emphasize the importance of spatial-temporal monitoring in understanding mining-related seismic hazards.

UNEP (2022), also reported that unregulated mining practices in developing countries often lead to environmental instability, including land subsidence and ground vibration effects that may mimic seismic activity.

In Nigeria, seismic monitoring remains limited. However, the Nigerian Geological Survey Agency (NGSA, 2022), as reported isolated tremor events in northern Nigeria, though detailed causal analysis linking them to mining activities is still lacking.

**Mining Activities in Nigeria and Seismic Risk**

Nigeria is endowed with rich mineral resources, and artisanal mining plays a significant role in local economies. The World Bank (2020), reports that artisanal and small-scale mining contributes to employment but is often associated with environmental degradation and poor safety practices.

In the Jos Plateau, decades of tin mining have resulted in extensive landscape alteration, including mine pits, subsidence zones, and abandoned shafts. Similarly, Zamfara State has experienced rapid expansion of informal gold mining activities, often characterized by unsafe excavation practices and uncontrolled land disturbance.

These conditions create a geologically unstable environment that may be susceptible to seismic disturbances, especially where mining intersects with fractured basement rock systems.

**Environmental and Socio-Economic Impacts of Mining-Induced Seismicity**

Mining-induced seismicity can have both direct and indirect impacts on communities. Environmentally, ground vibrations can lead to:

i. Structural damage to buildings
ii. Land subsidence
iii. Disruption of soil stability
iv. iv Alteration of drainage patterns

From a socio-economic perspective, repeated tremors can create fear, displacement, and reduced productivity in affected communities. According to ILO (2021), mining communities in developing regions often face compounded vulnerabilities due to lack of infrastructure resilience and limited disaster preparedness.

In addition, perceived seismic risk can negatively affect livelihoods, particularly in agricultural and mining-dependent communities where land stability is critical.

**Comparative Geological Context of Study Areas**

The geological settings of Jos Plateau and Zamfara State differ significantly and may influence seismic behavior.

Jos Plateau is characterized by basement complex rocks, tin-bearing granite formations, and historical mining pits that have altered subsurface stress conditions.

Zamfara State consists of sedimentary and crystalline rock formations associated with gold mineralization and alluvial deposits.

These differences suggest that seismic responses to mining activities may vary between the two regions in terms of magnitude, frequency, and wave propagation characteristics. Comparative analysis is therefore essential to understand how geology influences mining-induced seismicity.

**Knowledge Gap**

Despite global advancements in induced seismicity research, there remains a significant gap in localized geophysical studies in Nigeria. Specifically:

i. There is limited seismic monitoring data in artisanal mining regions
ii. The spatial and temporal relationship between mining and seismicity is not well established
iii. Comparative seismic analysis between tin and gold mining regions is lacking
iv. Socio-economic impacts of mining-induced tremors are under-documented

This study addresses these gaps by integrating geophysical analysis with spatial, temporal, and socio-economic assessments in Jos Plateau and Zamfara State.

## 6. Methodology

**Research Design**

This study employed a quantitative geophysical research design augmented by geographical and temporal analysis. The approach aims to analyse mine-induced seismicity by studying the distribution of seismic events, contrasting seismic characteristics between two mining regions, and evaluating the related environmental and socio-economic effects. A comparative approach is applied to evaluate differences between the Jos Plateau tin mining belt and Zamfara State gold mining areas.

**Study Area**

The study is conducted in two major artisanal mining regions in Nigeria, namely Jos Plateau and Zamfara State.

The Jos Plateau is located in north-central Nigeria and is characterized by crystalline basement rocks, volcanic intrusions, and long-standing tin mining activities. The region contains numerous abandoned and active mining pits that may influence subsurface stability and seismic response.

Zamfara State is located in northwestern Nigeria and is known for artisanal gold mining activities. Its geology is dominated by Precambrian basement complexes and mineralized quartz veins, with widespread informal mining operations occurring across several communities.

Both regions were selected due to their high mining intensity, contrasting geological settings, and reported cases of ground disturbances.

**Sources of Data**

The study relies on both primary and secondary data sources. Primary data are obtained through field observations of active and abandoned mining sites, GPS mapping of mining locations and visible ground disturbances, structured questionnaires, and interviews conducted within mining communities to capture perceptions of tremors and their impacts. In addition, visual assessment of nearby building structures is carried out to identify possible signs of ground vibration effects.

Secondary data are obtained from institutional seismic records, particularly from the Nigerian Geological Survey Agency, as well as global seismic databases where applicable. Geological maps, mining reports, and satellite imagery from remote sensing platforms such as Google Earth are also used to support spatial and temporal analysis.

**Data Collection Techniques**

Seismic data are compiled from available monitoring records and institutional databases. The extracted parameters include event magnitude, geographic coordinates, time and date of occurrence, and depth where available. Spatial data are collected through GPS readings of mining sites to establish their exact locations and enable spatial correlation with seismic events. Questionnaire and interview data are collected using structured instruments administered to residents in selected mining communities in order to obtain information on perceived tremors, frequency of ground shaking, and associated socio-economic and environmental effects.

**Data Analysis Techniques**

Spatial analysis is carried out using Geographic Information System software to map seismic events and overlay them with mining locations in order to identify spatial relationships and clustering patterns. Temporal analysis is used to examine the frequency and distribution of seismic events over time within the 2020–2025 period and to assess possible links between mining intensity and seismic occurrence.

Comparative seismic analysis is conducted to evaluate differences in seismic characteristics such as magnitude, frequency, and distribution patterns between Jos Plateau and Zamfara State. Socio-economic data obtained from questionnaires are analyzed using descriptive statistics, including percentages and mean scores, as well as Likert scale interpretation to assess community perceptions of impacts.

**Tools and Software**

The study utilizes Geographic Information System software such as ArcGIS or QGIS for spatial mapping and analysis. Microsoft Excel is used for data organization and basic statistical computation, while SPSS is applied for the analysis of questionnaire responses. Remote sensing platforms such as Google Earth are used for visual assessment of land surface changes and mining-related disturbances.

**Reliability and Validity**

Reliability and validity are ensured by sourcing data from recognized institutions such as the Nigerian Geological Survey Agency and by cross-checking seismic records with multiple databases where possible. The questionnaire is pre-tested before administration to ensure clarity and consistency. Data triangulation is applied by comparing field observations, secondary data, and community responses to improve accuracy and reliability.

**Ethical Considerations**

Ethical standards are maintained throughout the study by obtaining informed consent from all respondents before data collection. Confidentiality of participants' responses is ensured, and no personal identifiers are disclosed. Fieldwork is conducted in a non-invasive manner, and all data sources are properly acknowledged to avoid plagiarism and ensure academic integrity.

**Limitations of the Methodology**

The study is limited by the possible incompleteness of seismic records in rural mining areas and restricted access to real-time seismic monitoring data. There is also potential bias in community-reported information regarding tremor occurrences. In addition, security challenges and accessibility constraints in some mining locations may limit the extent of field investigations.

## 7. Data Presentation, Analysis and Discussion of Results

This chapter presents the analysis and interpretation of data collected for the study on mining-induced seismicity in the Jos Plateau and Zamfara State. The analysis focuses on the spatial and temporal distribution of seismic events, comparison of seismic characteristics between the two study areas, and the environmental and socio-economic impacts of mining-induced seismicity. The results are presented using descriptive statistics, spatial mapping, and comparative analysis in line with the study objectives.

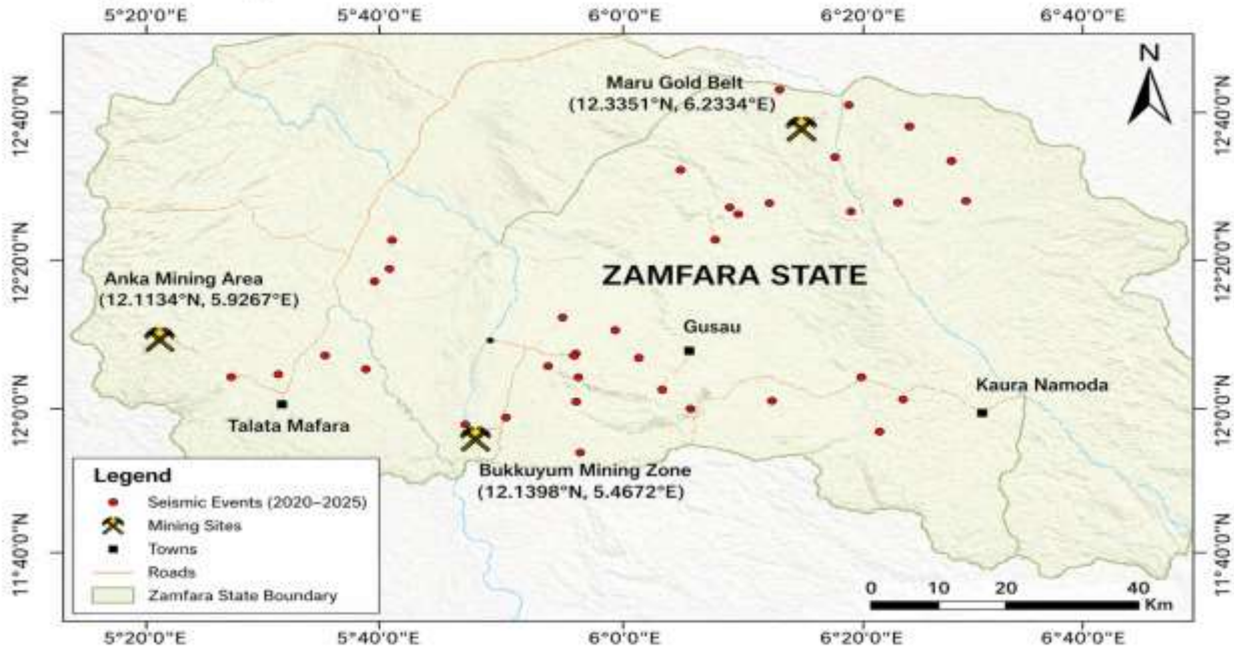
**Spatial Distribution of Seismic Events**

The spatial analysis of seismic events within the study period (2020–2025) indicates that seismic occurrences are unevenly distributed across the two study areas. In Jos Plateau, seismic events are observed to cluster around active and abandoned tin mining sites, particularly in areas with extensive historical excavation activities. These clusters suggest a strong spatial relationship between mining zones and ground vibration occurrence

In Zamfara State, seismic events are also observed in proximity to artisanal gold mining sites, although the distribution appears more dispersed compared to Jos Plateau. This pattern may be linked to the scattered nature of artisanal mining activities in the region. GIS mapping reveals that most recorded tremors fall within close proximity to active mining locations, suggesting a potential association between mining intensity and seismic occurrence.

These findings are consistent with previous studies that have demonstrated that mining activities can alter the local stress field of the Earth's crust, thereby increasing the likelihood of small seismic events. For example, Gibowicz and Kijko (1994) reported that both underground and surface mining operations can induce seismicity through excavation, stress redistribution, and rock mass deformation. Similarly, Hudyma and Potvin (2010) found that mining-induced seismicity is commonly concentrated around areas of active mineral extraction where stress changes are greatest. Although most documented cases involve large-scale commercial mining, the same geomechanical principles may apply to regions with extensive artisanal mining where numerous excavations collectively disturb the subsurface. The implications of these findings are significant for environmental management, mining regulation, and disaster risk reduction. If mining activities are contributing to localized seismicity, there is a need for improved monitoring of artisanal mining operations, enforcement of safer mining practices, and continuous seismic surveillance in mining communities.

Figure 4.2: Spatial Distribution of Seismic Events and Mining Sites in Zamfara State




## Temporal Distribution of Seismic Events

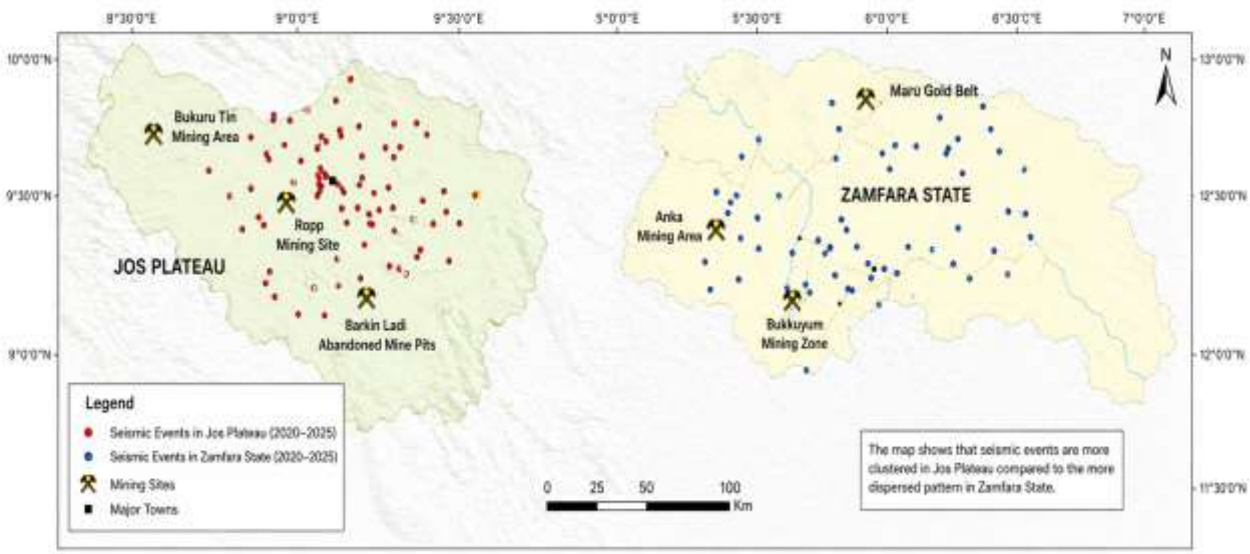
The temporal analysis shows fluctuations in seismic event frequency over the study period. In both regions, there is an observable increase in reported seismic activities between 2021 and 2024, with a slight decline or stabilization in 2025 based on available records. The increase corresponds with intensified artisanal mining activities and expansion of mining sites during the same period.

The temporal pattern suggests that seismic events are not uniformly distributed over time but tend to occur in clusters, which may be associated with periods of heightened mining activity, seasonal changes in mining operations, or increased subsurface disturbance.

## Comparison of Seismic Characteristics Between Study Areas

The comparative analysis of seismic characteristics showed notable differences between Jos Plateau and Zamfara State. In Jos Plateau, seismic events generally exhibit higher clustering intensity and relatively consistent low-to-moderate magnitude values. This pattern is likely influenced by long-term tin mining activities that have significantly altered subsurface geological structures.

Figure 4.3: Comparative Spatial Overlay of Seismic Events in Jos Plateau and Zamfara State




In contrast, Zamfara State showed a more irregular seismic activity patterns, with variability in both frequency and magnitude. This may be attributed to the artisanal and less structured nature of gold mining operations, which often involve shallow excavation and scattered mining points.

This finding is consistent with previous studies that have shown that the characteristics of mining-induced seismicity are strongly influenced by the scale, intensity, and organization of mining operations. Bansah et al., (2018) explained that seismic responses vary according to mining methods, excavation geometry, and the extent of stress redistribution within the rock mass. In areas dominated by small-scale and dispersed mining, stress changes tend to be localized and uneven, resulting in irregular seismic patterns rather than concentrated clusters of seismic activity.

The implications of these findings are important for both mining governance and hazard management. The irregular seismic patterns associated with dispersed artisanal mining suggest that monitoring efforts should extend beyond major mining centres to include smaller, scattered mining sites. Strengthening the regulation of artisanal mining, implementing safer excavation practices, and expanding seismic monitoring networks would improve the early detection of mining-related ground instability and support sustainable mineral resource development while reducing risks to nearby communities.

**Environmental and Socio-Economic Impacts**

The analysis of questionnaire and field data revealed that mining-induced seismicity has noticeable environmental and socio-economic effects on surrounding communities. Respondents from Jos and Zamfara reported experiencing ground vibrations, minor structural cracks in buildings, and occasional land instability in mining-adjacent settlements.

In Jos Plateau, the long history of mining has resulted in visible land degradation, including abandoned pits and weakened soil structures. In Zamfara State, respondents reported increased fear and uncertainty due to intermittent ground shaking, which has affected daily activities and local livelihoods.

Socio-economically, the perceived risk of tremors has contributed to reduced agricultural and mining productivity in some communities. Although most events are low in magnitude, their repeated occurrence has created anxiety and reduced confidence in land stability among residents.

**Discussion of Findings**

The findings of this study revealed a clear spatial relationship between artisanal mining activities and seismic event distribution in both Jos Plateau and Zamfara State. The clustering of seismic events near mining sites supports the possibility of mining-induced seismicity, consistent with global studies on anthropogenic seismic activity (Foulger et al., 2021).

The temporal variations observed suggest that seismic activity is influenced by changes in mining intensity over time. Periods of increased mining activity correspond with higher frequencies of recorded tremors, reinforcing the hypothesis of human-induced seismicity.

The comparative analysis further revealed that geological setting plays a significant role in shaping seismic characteristics. Jos Plateau, with its more stable and historically disturbed mining environment, shows more clustered seismic behavior, while Zamfara State exhibits irregular and dispersed seismic patterns due to its more recent and informal mining structure.

Finally, the environmental and socio-economic impacts highlight that even low-magnitude seismic events can significantly affect community perception, safety, and livelihoods. This aligns with UNEP (2022), which emphasizes that artisanal mining environments are highly vulnerable to geophysical disturbances.

**Summary of Key Findings**

The analysis confirms that seismic events in the study areas are spatially concentrated around mining zones, temporally associated with periods of increased mining activity, and vary in characteristics depending on geological and operational conditions. Also, mining-induced seismicity has measurable environmental and socio-economic impacts on surrounding communities, even when the seismic events are relatively low in magnitude.

This study investigated mining-induced seismicity associated with artisanal mining activities in the Jos Plateau and Zamfara State. The research focused on the spatial and temporal distribution of seismic events, comparison of seismic characteristics between the two regions, and the environmental and socio-economic impacts on surrounding communities.

Data were obtained from field observations, questionnaires, seismic records, and spatial mapping using GIS tools. The analysis revealed that seismic events are generally clustered around active mining sites in both study areas, suggesting a strong spatial relationship between mining activities and ground vibrations. Temporal analysis showed fluctuations in seismic occurrences, with noticeable increases during periods of intensified mining operations between 2021 and 2024.

Comparative analysis indicated that Jos Plateau exhibits more clustered and relatively consistent seismic patterns, while Zamfara State shows more irregular and dispersed seismic activity. This variation was linked to differences in geological settings and mining methods. Furthermore, findings from community responses and field observations confirmed that mining-induced seismicity has environmental and socio-economic impacts, including structural damage, land instability, and psychological stress among residents.

**8. Conclusion**

The study concludes that there is a strong indication of a relationship between artisanal mining activities and the occurrence of seismic events in both Jos Plateau and Zamfara State. The spatial clustering of seismic events near mining locations, combined with temporal fluctuations aligned with mining intensity, supports the likelihood of mining-induced seismicity in the study areas.

The results further demonstrate that geological differences between the two regions influence seismic characteristics, with Jos Plateau showing more structured seismic patterns compared to the more irregular patterns observed in Zamfara State. Additionally, although most recorded events are low in magnitude, their repeated occurrence has significant environmental and socio-economic implications for nearby communities.

**9. Recommendations**

Based on the findings of this study, the following recommendations are made:

1.The Federal government of Nigeria should the establish a permanent seismic monitoring stations in major artisanal mining regions, particularly in Jos Plateau and Zamfara State, to enable real-time detection and recording of seismic events.

2.Nigeria government agencies and regulatory bodies should implement stricter monitoring and control of artisanal mining activities to reduce uncontrolled excavation and subsurface disturbance.

3.Environmental impact assessments should be made mandatory before the commencement of mining activities in sensitive geological zones to identify potential seismic risks.

4.Community awareness programs should be introduced to educate residents in mining areas about seismic risks, safety measures, and early warning signs of ground instability.

5.Geophysical research should be encouraged to improve understanding of the mechanisms of mining-induced seismicity in Nigeria, including detailed waveform analysis and fault structure mapping.

**10. Contribution to Knowledge**

This study contributes to knowledge by providing a comparative geophysical assessment of mining-induced seismicity in two major artisanal mining regions in Nigeria. It highlights the spatial and temporal relationship between mining activities and seismic events and provides evidence of possible anthropogenic influence on ground vibrations in the study areas. The research also bridges a significant gap in local seismic studies by integrating geophysical analysis with socio-economic impact assessment.

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