



Investigation of Earth Tremor Occurrences in Nigeria Using Shuttle Radar Topographic Mission (SRTM) Data and Aeromagnetic Data

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KEYWORDS

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ABSTRACT

Earth tremors, though often low in magnitude, represent critical indicators of crustal instability and potential seismic hazards. Nigeria, traditionally considered a region of low seismic risk, has recorded recurrent tremor events across the northcentral and southwestern regions, raising questions about the tectonic and geodynamic processes driving these disturbances. This study integrates Shuttle Radar Topographic Mission (SRTM) data with aeromagnetic datasets to investigate the relationship between surface lineaments, subsurface structures, and tremor occurrences in these regions. SRTM analysis reveals that most tremor epicenters occur near elevated terrains, where topographic loading and structural complexity enhance seismic susceptibility. Aeromagnetic interpretations using tilt derivative techniques delineate major and minor fault systems, showing that tremors in Abuja and Kwoi align with a major NE–SW fault system linked to the offshore Romanche fracture zone, while those in the southwest are associated with intersecting NE- and NW-trending fractures. Curie Point Depth (CPD) estimates further highlight lithospheric thinning in the northcentral region (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, reflecting far-field plate stresses. The results demonstrate that Nigeria's seismicity is driven by a combination of plume-related magmatism, lithospheric weakness, and far-field tectonic forces. These findings provide a preliminary geophysical framework for understanding tremor genesis in intraplate settings and underscore the need for improved seismic monitoring and hazard preparedness in Nigeria.

CITATION

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INTRODUCTION

The investigation of earth tremor occurrences has gained renewed attention globally as regions previously considered tectonically stable increasingly report seismic disturbances of varying magnitudes (Oyibo and Kadiri, 2023). An earth tremor, often defined as a low-magnitude

earthquake, represents the localized release of stress within the Earth's crust. Although smaller than major earthquakes, tremors can provide vital insights into subsurface instabilities, and in some cases, they serve as precursors to larger seismic events (Adib and Kianoush, 2025). Their impacts, though sometimes subtle, may

include ground failures, resonance, and infrastructural damage, which cumulatively underscore the importance of scientific investigation.

Nigeria, situated outside the major global seismic belts, has historically been considered a region of low seismic risk. However, records dating back to the 1930s reveal repeated tremor events, with notable occurrences in Oyo, Kaduna, and most recently the Federal Capital Territory (FCT), Abuja (Akpan and Yakubu, 2010). The recurrence of these events, coupled with their increasing frequency in recent decades, has raised concern over the stability of the Nigerian continental crust. These seismic disturbances suggest possible reactivation of dormant tectonic structures or deeper crustal processes from far-field plate motions and or magmatization thereby leading to crustal rifting. Yet, the precise mechanisms responsible for these tremors remain poorly constrained due to the paucity of integrated geophysical studies in the region.

Understanding whether Nigerian tremors are linked to far-field plate motions or plume dynamics is crucial for developing a preliminary model of the country's seismicity. Such knowledge will not only provide insight into the tectonic framework of Nigeria but will also support proactive hazard assessment and disaster mitigation strategies. To achieve this, the application of geophysical datasets with the ability to probe both surface and subsurface structures has become indispensable.

Recent advancements in geospatial and aeromagnetic methods have demonstrated considerable potential in the study of seismicity and crustal dynamics. Shuttle Radar Topographic Mission (SRTM) data, through shaded-relief and illumination-based filtering techniques, enhances the detection of surface lineaments and faults that may control tremor occurrences. Similarly, High-Resolution Aeromagnetic (HRAM) data provides critical subsurface information by delineating structural discontinuities and estimating Curie Point Depths (CPD), which serve as

indicators of lithospheric thickness and geothermal gradients (Bello et al 2025; Blakely, 1995; Tanaka et al., 1999). Applications of these methods in tectonically active regions such as East Africa (Ebinger et al., 2017), the Himalayas (Mishra et al., 2012), and Southeast Asia (Vijaya and Damodara, 2022) have demonstrated their effectiveness in linking structural and thermal anomalies with seismicity. Their adoption in intraplate settings, such as Nigeria, therefore offers an opportunity to establish whether observed tremor events are products of active tectonism or reactivated structures.

Against this background, this study focuses on the investigation of earth tremor occurrences around the northcentral and southwest regions of Nigeria using Shuttle Radar Topographic Mission (SRTM) data and aeromagnetic data. The datasets were interpreted to map lineaments and rift structures in tremor epicenters within the regions. The SRTM data will provide insight of the topographic influence on the tremors while the Curie Point Depths (CPD) will estimate the level of lithospheric thinning within the areas of study. Integrating SRTM and aeromagnetic datasets in this research therefore provides a comprehensive geophysical framework for understanding the mechanisms behind Nigeria's tremor occurrences.

Study Area

Events of earth tremor have been reported in various locations in Nigeria, but the focus of this research is on parts of the central region (longitude 7.0°E - 9.5°E; latitude 8.5 ° N– 10.5 ° N, and the southwestern (SW) region (longitude 3.0°E – 5.5°E; Latitude 6.0°N– 8.0°N. The areas are within the basement complex of Nigeria (see Figure 1). The detailed geology of these regions have been reported by several researchers (Eludoyin et al., 2023; Okunlola et al., 2022; Oyinloye, 2011; Goki et al., 2020; Omeje et al., 2013).

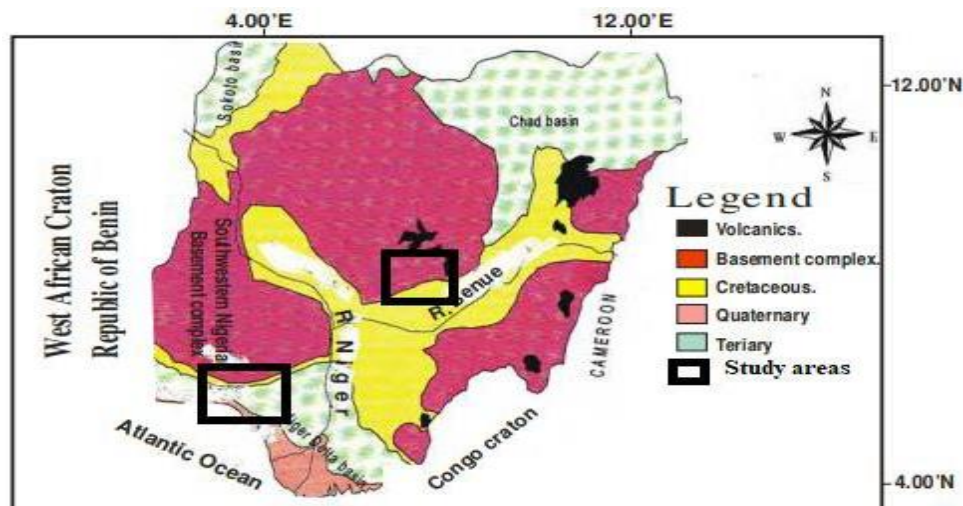


Figure 1: Geology of the study area. Modified after Oyinloye (2011).

MATERIALS AND METHODS

Materials

The primary material used in this study is SRTM and aeromagnetic data. The topographic data used are derived from the SRTM (Shuttle Radar Topography Mission) model. The processing of the collected data and transformation of the maps were performed using the software Global Mapper 18.1 and Oasis Montaj 8.4. The aeromagnetic data were sourced from the Nigerian Geological Survey Agency (NGSA). The parameters adopted in collecting the data have been widely reported (Shuaibu et al 2022; Bello et al 2024; Bello et al 2025 a & b; Oyibo et al 2022).

Methods

The gridded topography dataset was mapped using Oasis Montaj to present the spatial topographic variation of the study areas. The manifestation of linear structures is achievable with the application of edge detection techniques on aeromagnetic data; vertical derivatives, analytic signal, total horizontal derivative, theta map, tilt derivative etc. Tilt derivative was adopted in this research due to its uniqueness in mapping lineaments.

The tilt derivative is a geometrical function of the vertical (dF/dz) and horizontal (dF/dx and dF/dy) derivatives of the field F , with values between $\pm\pi/2$. The tilt derivative (TD) as normally calculated is given by

$$TD = \tan^{-1} \left(\frac{dF/dz}{\sqrt{(dF/dx)^2 + (dF/dy)^2}} \right) \quad (1)$$

The curie depth estimation technique is a veritable tool for delineating crustal thinning within the basement. The depth is that which a magnetic material loses its magnetic properties due to Curie temperature. Various methods of estimating curie depth have been reported (Salem et al 2014; Muhammad et al 2025).

Estimating the Curie depth requires calculating depth to the top Z_t and depth to the centroid Z_o from spectral plots of

$$\ln(P(k)) = B - 2|2\pi k|Z_t \quad (2)$$

and

$$\ln P(k)^{1/2}/|2\pi k| = D - |2\pi k|Z_o \quad (3)$$

$$\text{The Curie depth, } Z_b = 2Z_o - Z_t \quad (4)$$

RESULTS AND DISCUSSION

In the northcentral region, elevations range from 151.9m to 1294.8m (Figure 2), with the reported tremor locations in Kwoi and Abuja at elevations of 796m and 515m respectively. In the southwestern region, elevations vary between 0 and 610 m (Figure 3) with epicenters in Lagos (4.1 m), Abeokuta (85 m), Shagamu (23.8 m), Ijebu-Ode (85 m), Okitipupa (18.4 m), Ile-Ife (239.9 m), and Akure (421.9 m) occurring at moderately elevated terrains. With the exception of Lagos, Shagamu, and Okitipupa, most of these epicenters are situated near mountainous areas. Large topographic relief, such as high mountains, can influence the magnitude and impact of earth tremors in many ways. Firstly, Stress Loading from Mountain Mass adds enormous weight to the lithosphere thereby causing additional stress on underlying faults, and when these faults eventually slip, the accumulated stress can contribute to larger-magnitude earthquakes. Secondly, mountain ranges are created by tectonic compression, which produces many faults and thrust systems and more faults implies more potential rupture areas, which can amplify seismic energy release. Thirdly, steep relief within mountainous regions can cause seismic waves to be trapped, reflected and then amplified. This is a possible reason why most of the tremors are located within mountainous regions especially for the tremor reported at Kwoi in which case the epicenter was reported to be out the mountainous region (Goki et al., 2020).

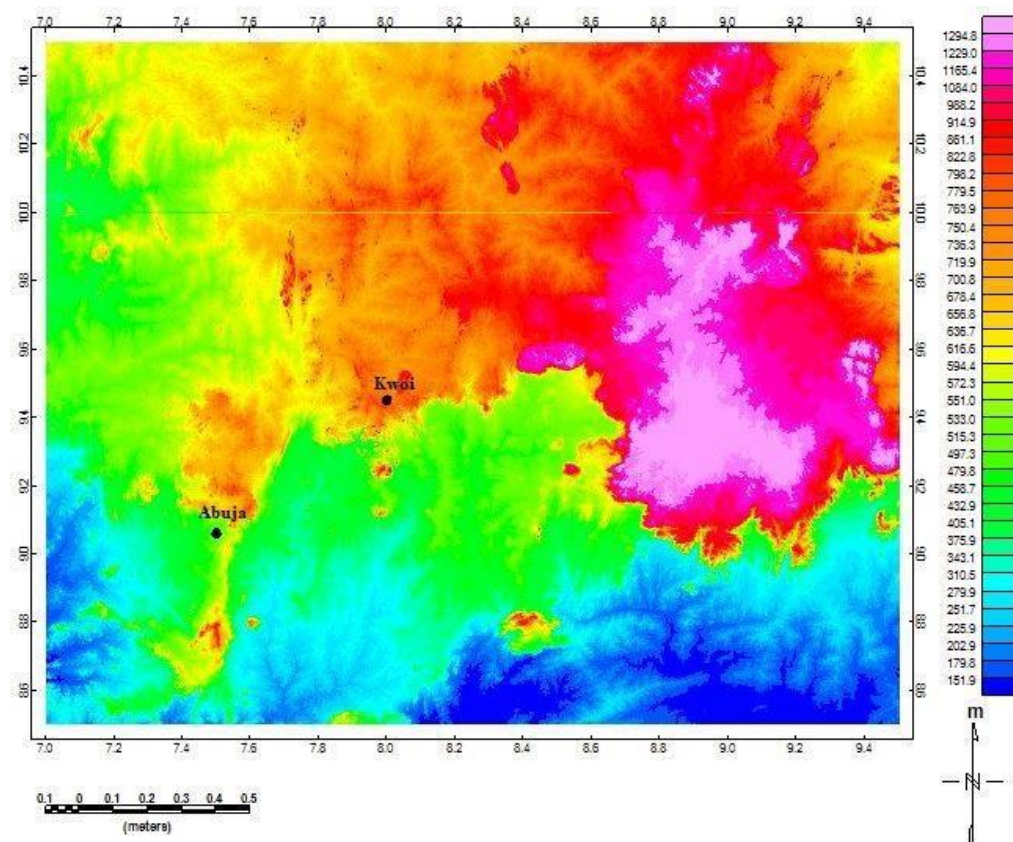


Figure 2: SRTM map of part of Northcentral Nigeria showing locations of reported earth tremors

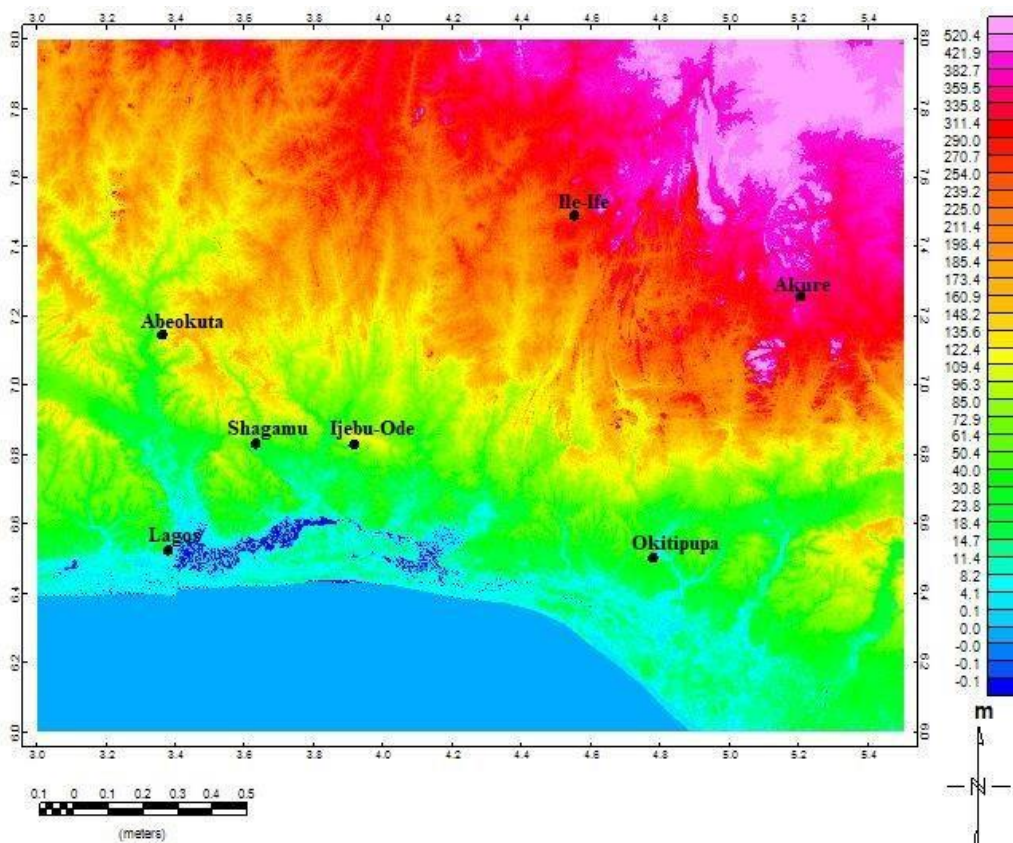


Figure 3: SRTM map of southwest Nigeria where earth tremors were reported

Figure 4 and Figure 5 shows the tilt derivative maps for the northcentral and southwest regions respectively. The lineaments shown are derived visually and they represent subsurface structures resulting from sharp magnetic contrasts. The tilt derivative (TDR) enhances and sharpens anomalies over causative bodies, thereby reducing interpretational complexity and enabling clearer imaging of subsurface structures. The inferred lineaments generally represent faults, fractures, folds, lithological contacts, and, in some cases, the geometry of intrusive bodies, providing critical insights into structural frameworks (Oyibo et al., 2022). Areas exhibiting increased fracturing and zones of deep, regional, or local faults often correspond to loci of seismic dislocation and represent potential sites for significant earthquake activity (Ostapenko et al., 2022).

As can be seen in Figure 4 the northcentral region is dominated by lineaments trending along NE – SW directions. The geology in this region is dominated by migmatized gneisses, schists, quartzites, and minor

amphibolites, intruded by granitoids ranging from Pan-African to Jurassic suites that form undulating whaleback terrains. Goki et al. (2020) reported similar NE – SW foliations of these metamorphic units. It can also be observed that Kwoi and Abuja tremor locations lie in the direction and falls within a major fault zone that coincides with the off-shore Romanche fault line and this is consistent with reports made by Oyibo and Kadiri (2023). In contrast, the southwestern region (Figure 5) is characterized by many minor fault and fracture systems along NE – SW and NW – SE directions which is also in agreement with the regional foliation and tectonic emplacement of the Nigerian Basement Complex (Dasho et al., 2020). Lineaments around Lagos, Shagamu, Ile-Ife, and Akure are predominantly NE- trending, while those near Abeokuta and Okitipupa trend NW. Notably, the epicenter at Ijebu-Ode is located on crosscutting lineaments trending NE and NW, highlighting localized structural complexities that may facilitate seismic activity.

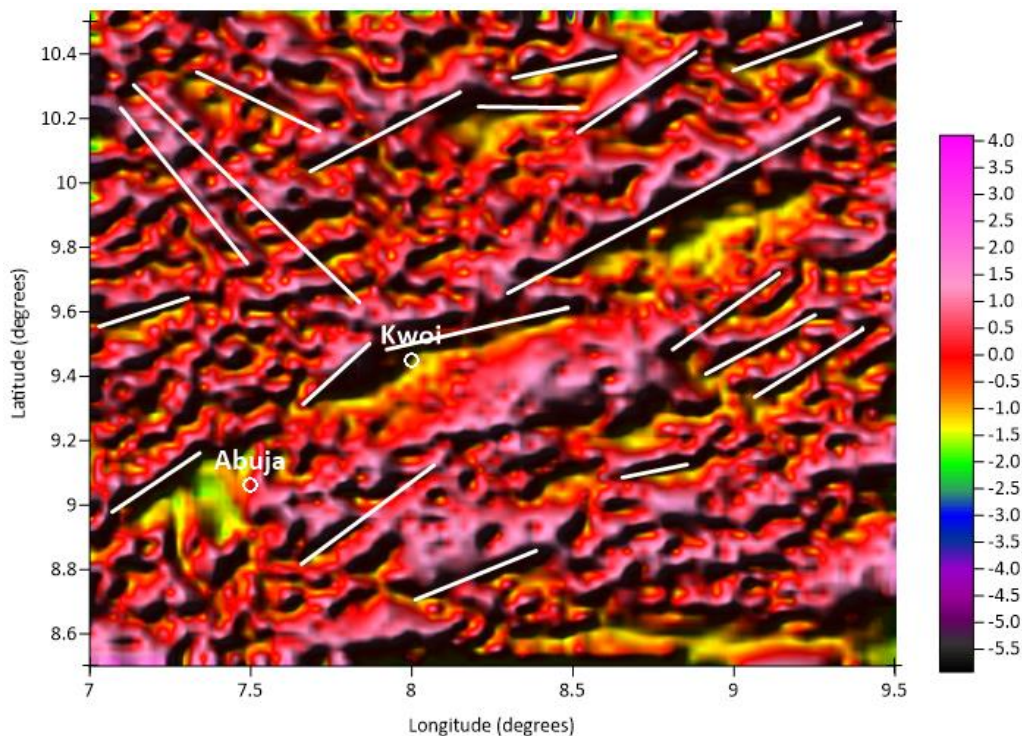


Figure 4: Tilt derivative map showing lineaments within north central Nigerian Basement Complex

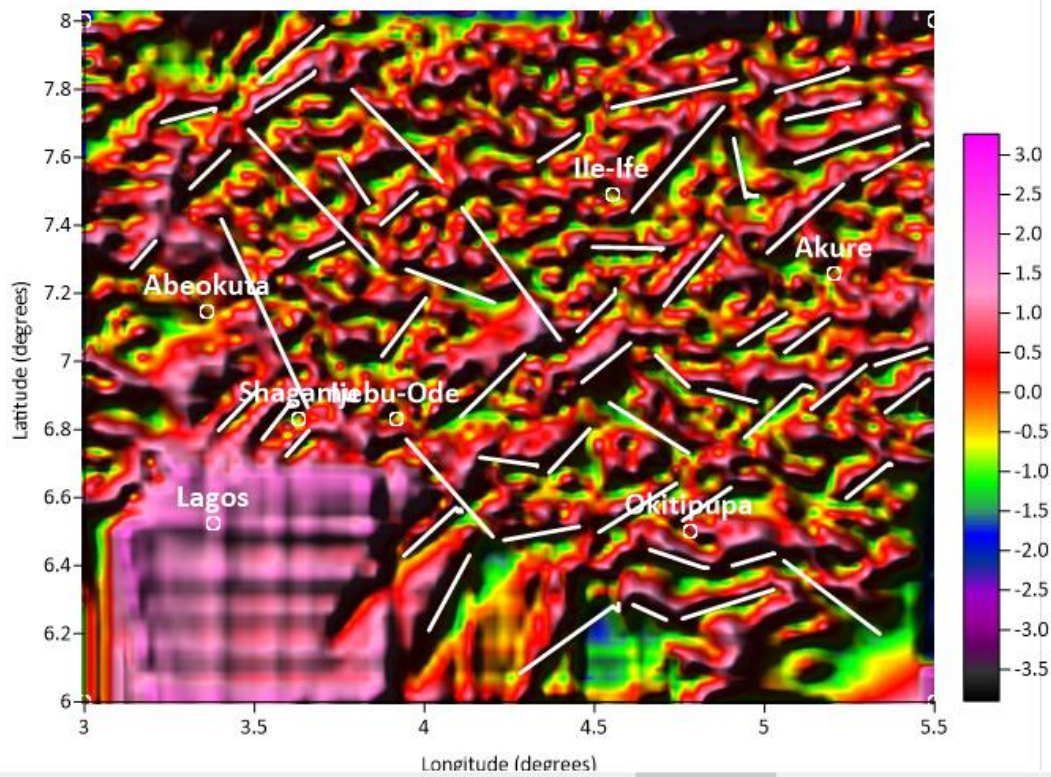


Figure 5: Tilt derivative map showing lineaments within southwestern part of Nigeria

In this study the computed CPD values vary significantly for both regions (see Figures 6 and 7). The northcentral region records depths between 1.6 km and 13 km (Figure 6), while the southwestern region ranges from 7.2 km to 13 km (Figure 7). At tremor epicenters, CPD values are estimated at 12.5 km in Kwoi and 7.9 km in Abuja. In the southwest, Abeokuta, Shagamu, Ijebu-Ode, Okitipupa, Akure, and Ile-Ife exhibit CPD values of 10.3 km, 10.2 km, 9.2 km, 10.4 km, 10.5 km, and 9.4 km, respectively. Other rift margins in Africa such as the Ethiopian Rift System (ERS) show CPD values ranging from 8.85 km to 55.85 km with near rift boundaries CPD of approximately 12 km within volcanic and geothermal zones (Hilemichaeil et al., 2024). This strengthens the point that shallow or relatively low CPD values in tectonically reactivated or rifted zones indicates lithospheric thinning. The range of CPD values obtained in this work therefore suggest possible structurally weak zones within the Nigerian lithosphere that may account for tremor activity.

It can be observed generally that CPD values within the northcentral region are generally lower than those at the southwestern region showing that despite the relatively thicker crust in the southwest the large number of tremor events recorded are as a result of far-field plate motions probably caused by forces which gave rise to the Romanche fault line of the coast of Nigeria. Alignment of Kwoi and Abuja tremor locations with this trend suggests an extension of the influence of such force deep into the northcentral Basement Complex of Nigeria. The low values of CPD obtained in the northcentral region therefore suggest lithospheric thinning resulting from plume dynamics, probably from the St Helena plume that gave rise to the volcanism registered on the Jos plateau (Coulon et al., 1996; Oluwafemi, 2017). Combination of these two events which is responsible for the seismicity in the northcentral region make it similar to that of the East African Rift System which was as a result of mantle plume process and extensional stress.

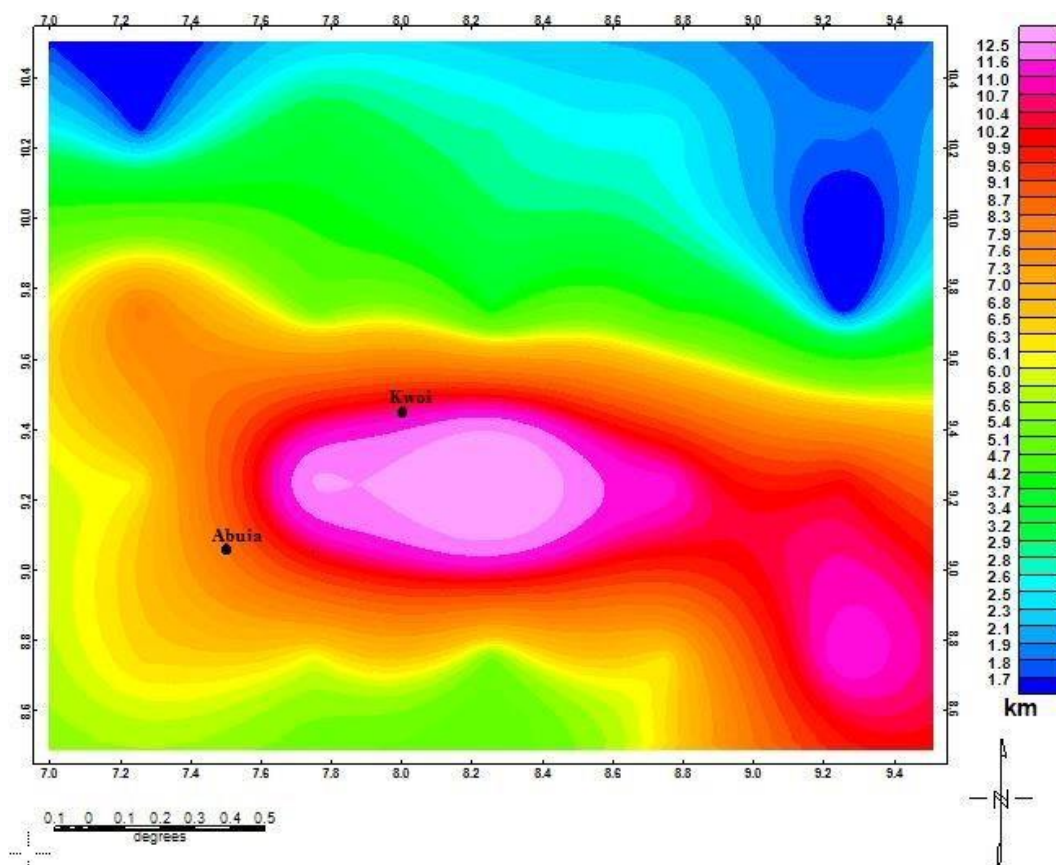


Figure 6: Curie point depth map for northcentral region of Nigeria

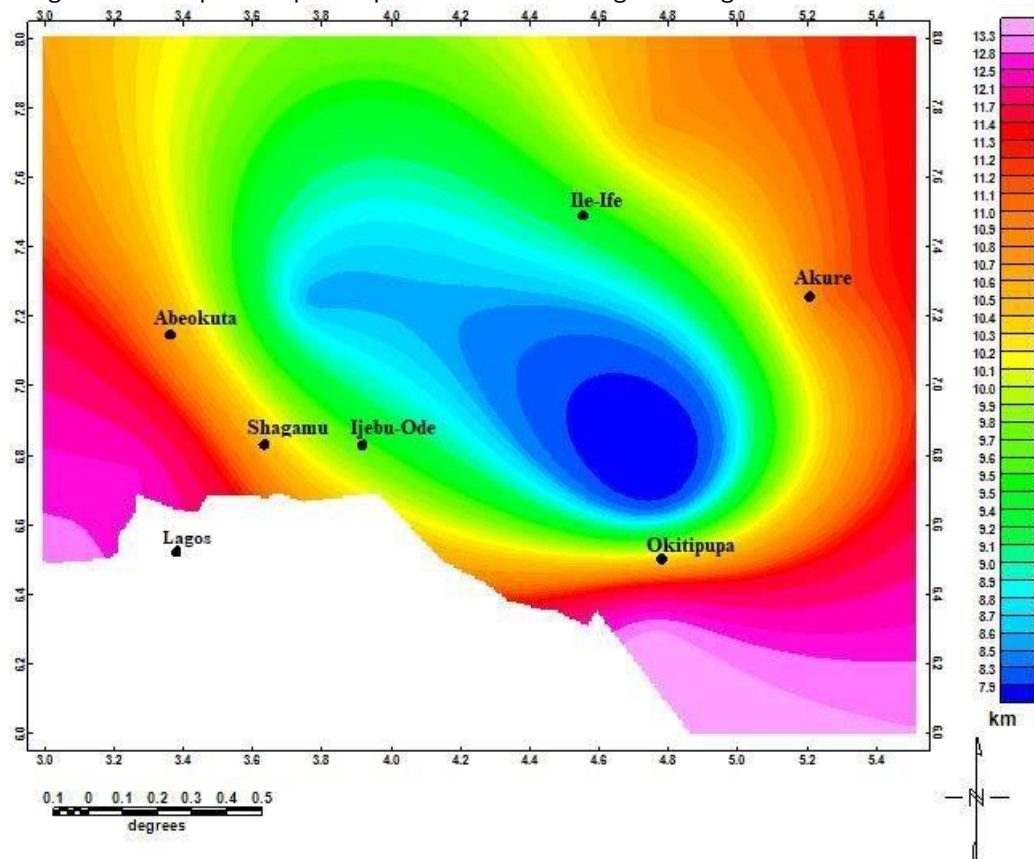


Figure 7: Curie point depth map of southwest region of Nigeria

CONCLUSION

This study integrates topographic, structural, and Curie Point Depth (CPD) analyses to provide new insights into the geodynamic setting of tremor-prone regions in Nigeria. The northcentral region is characterized by high-relief terrain with elevations reaching 1294.8 m, and this has positively influenced the magnitude and impact of earth tremors within the region. In the southwestern region tremor are located across a wider elevation range (4.1m – 421.9 m), with most events also situated near mountainous or moderately elevated terrains, except in Lagos, Shagamu, and Okitipupa, where tremor events must have been favoured by existence of crosscutting lineaments within the region. The structural framework reveals that Abuja and Kwoi lie along a major fault system, coinciding with the Romanche fault, whereas the southwestern epicenters are aligned with minor fault and fracture zones trending predominantly NE and NW. The crosscutting lineaments in Ijebu-Ode further underscore the structural complexity of the region. These results suggest that seismicity in northcentral region of Nigeria is linked to two activities, one along a major fault zone extending also to the Romanche fault and the other magmatism resulting from plume dynamics, while in the southwest CPD values indicates that the major source of tremors were connected with the Romanche fault but more diffusely controlled by secondary fractures and lineament intersections.

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