# SPATIO-TEMPORAL SEISMICITY ANALYSIS ALONG ACTIVE FAULT ZONES IN ALBANIA


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**ABSTRACT**

A spatio-temporal analysis of seismic activity along the active tectonic fault systems of Albania was conducted in early 2025 employing two diagnostic parameters: the fractal dimension (Dc), which characterizes the heterogeneity, complexity, and clustering of seismicity, and the standard normal deviate (Z), used to identify precursory seismic quiescence. The magnitude of completeness (Mc) across the Albanian fault zones ranges from 2.5 to 3.4, providing a solid basis for reliable interpretation. The obtained Dc value for the Albanian orogenic belt is 1.93 ± 0.04, indicating pronounced seismic clustering, particularly within the seven major fault zones at both regional and local scales. Seismic quiescence, commonly considered a potential precursor to strong earthquakes, proved effective in detecting anomalous patterns that may signal probable locations of future mainshocks. By integrating Dc and Z analyses, this study reveals structural complexities, seismogenic potential, and quiescence anomalies that go beyond conventional seismicity mapping. These findings enhance understanding of earthquake nucleation processes and support improved assessment of areas susceptible to future moderate-to-large seismic events in Albania.

***Keywords*:** Albanian faults, declustering, seismic quiescence, fractal dimension, seismic hazard

## 1. INTRODUCTION

Numerous regional and temporal studies have examined the space–time characteristics of earthquake activity worldwide, providing significant insights through the application of scaling laws (e.g., Mogi, 1962; Utsu, 1971; Mandelbrot, 1982; Habermann, 1983; Hirata, 1989; Wiemer and Wyss, 2000; Awad, 2005; Öncel and Wilson, 2007; Öztürk *et al*. 2008; Öztürk, 2011, 2015; Roy *et al*. 2011; Ormeni *et al*. 2017; 2023; Ormeni and Öztürk, 2024).

The Albanian region ranks among the most seismically active areas of the Balkan Peninsula, with numerous destructive earthquakes documented over the past two millennia in historical sources (Sulstarova *et al*. 1980; Aliaj *et al*. 2010; Ormeni and Öztürk, 2024). Situated within the Alpine–Mediterranean seismic belt, Albania accommodates part of the crustal deformation resulting from the collision between the Adriatic microplate and the Eurasian plate (Mazzoli and Helman, 1994).

During the last century, at least seven major earthquakes with magnitudes exceeding Ms 6.0 have affected the region: the 1905 Shkodra earthquake (Ms 6.6), the 1911 Ohrid Lake earthquake (Ms 6.7), the 1920 Tepelena earthquake (Ms 6.4), the 1926 Durrësi earthquake (Ms 6.2), the 1967 Dibra earthquake (Ms 6.7), the 1979 Montenegro earthquake (Ms 6.9), and the 2019 Durrësi earthquake (Ms 6.4) (Kociaj, 1986; Aliaj *et al*. 2010; Ormeni and Öztürk, 2024). More recently, a strong earthquake sequence began with the September 21, 2019 event (M 5.8), culminating in the November 26, 2019 Durrësi mainshock (M 6.4), located along the Adriatic fault zone approximately 35 km west of the capital city, Tirana (Ormeni and Öztürk, 2024).

This study focuses on the size-scaling characteristics of seismicity in Albania, with particular emphasis on regional, temporal, and magnitude distributions of earthquakes, as well as the parameters of magnitude completeness (Mc), fractal dimension (Dc), and precursory seismic quiescence (Z). All statistical analyses and visualizations, including histograms of regional, temporal, and magnitude distributions, were performed using the ZMAP software (Wiemer, 2001).

## 2. GEOLOGIC AND TECTONIC STRUCTURES IN AND AROUND ALBANIA

Albania lies within the Alpine-Mediterranean seismic belt and constitutes a convergent tectonic zone between the African and Eurasian lithospheric plates. The principal geological structures of Albania and its surroundings, collectively known as the Albanides, form a segment of the Dinaric–Albanid–Hellenic arc within the broader Alpine orogenic system. The primary source of seismicity in Albania is the ongoing collision between the Adriatic microplate and the Albanian orogen, which generates complex fault interactions and substantial strain accumulation throughout the region. This tectonic regime has produced numerous historical and instrumental earthquakes, including events with magnitudes up to M6.8, such as the 1851 Vlora, 1911 Pogradec, and 1967 Dibra earthquakes, as well as the M7.0 Ulqin earthquake in 1979. More recently, the ML6.4 earthquake in Durres on November 26, 2019 highlighted the persistent high seismic hazard of the region (Öztürk and Ormeni, 2021).

Focal mechanism solutions indicate a predominance of normal and thrust faulting, often accompanied by strike-slip components, reflecting the ongoing convergence between the Adriatic microplate and the Albanian orogen. The coexistence of these faulting styles highlights the complexity of the regional stress field and accounts for the spatial variability in seismic activity observed across different Albanian fault systems. This intricate tectonic framework renders Albania one of the most seismically active areas in the Mediterranean, emphasizing the necessity for detailed monitoring and continuous assessment of earthquake hazard.

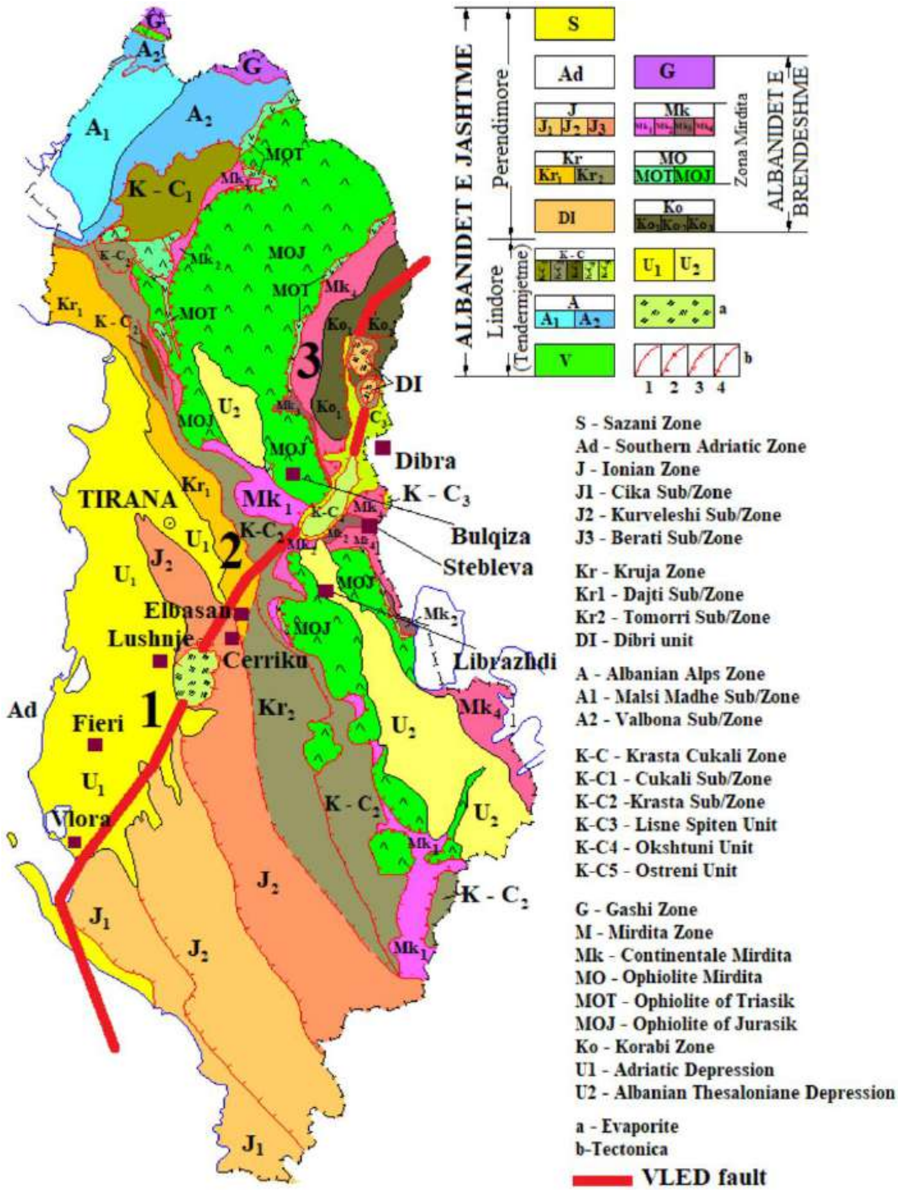


**Fig. 1:** Schematic tectonic and geologic map of Albania, where further details on the geologic, tectonic, and neotectonic processes in and around the country are provided (Aliaj *et al*. 2010). The internal units comprise the terrains east of the Kruja Zone, while the external units include the terrains of the Kruja, Ionian, and Sazani zones (Aliaj *et al*. 2010).

## 2. EARTHQUAKE DATA FOR THE TECTONIC FAULT SYSTEMS OF ALBANIA

The earthquake dataset used for this analysis was obtained from the Albanian Seismological Catalogue, and European Mediterranean Seismological Centre (EMSC) catalogue, covering the period from January 17, 1966, to December 31, 2024 (IGEO, 2025). This catalog includes all recorded earthquakes occurring along the Albanian fault zones and their surrounding regions. For the seismic quiescence analysis, the catalog was first declustered. Out of 38,816 earthquakes with $ML \geq 0.1$ recorded between 1966 and 2024, a total of 6,254 events (~16.1%) were identified as aftershocks or dependent events and subsequently removed. Assuming a magnitude of completeness of $Mc = 2.7$, an additional 22,284 earthquakes with $ML < 2.7$ were excluded. After declustering and completeness filtering, approximately 73.5% of the original catalog (28,538 events) were eliminated, resulting in a homogeneous and uniform dataset of 10,278 earthquakes, which served as the basis for the Z-value seismic quiescence analysis.

The analysis focused on shallow earthquakes (<70 km), as these events are most relevant for seismic hazard assessments and play a crucial role in identifying precursory quiescence anomalies, often associated with major crustal shocks. Focal depth analyses confirm that most earthquakes in the study area occur within the shallow upper and middle crust, consistent with the tectonic framework described previously in (Ormeni, 2010).

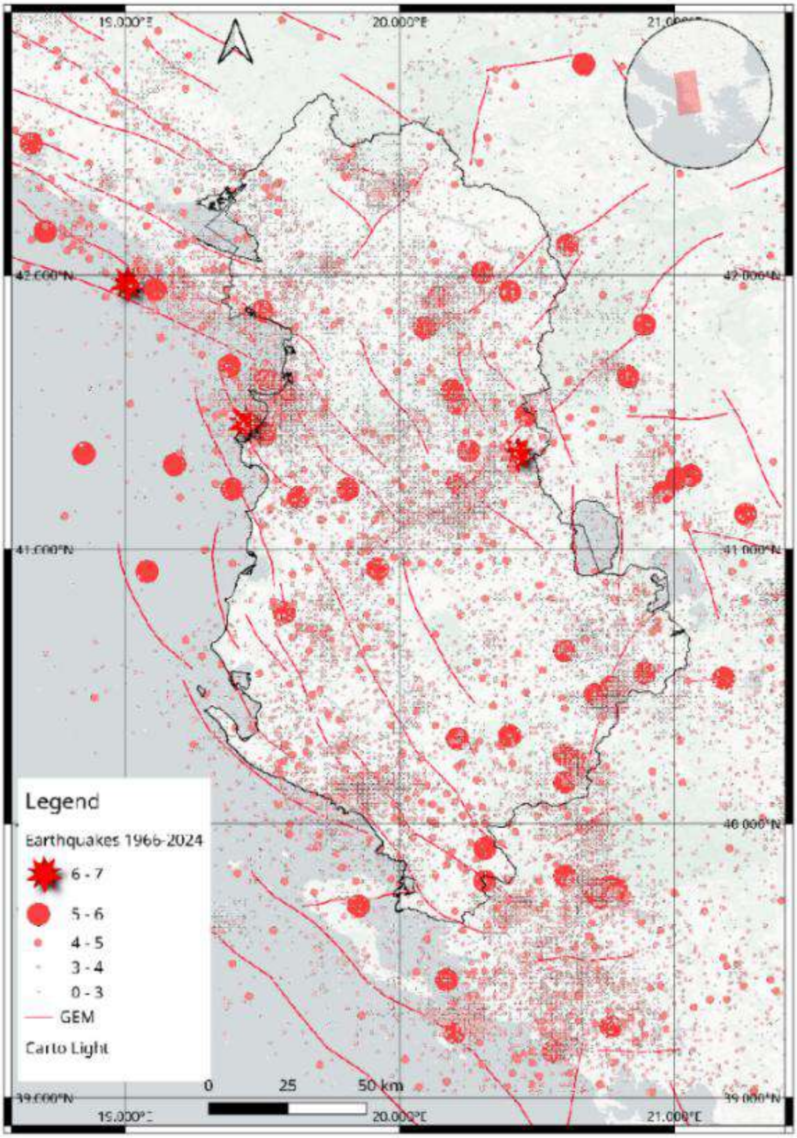


**Fig. 2:** Epicentral distribution of earthquakes events are displayed with different symbols according to their magnitude ($M_L \geq 0.1$) and for strong mainshocks ($M_L \geq 6.0$, marked with a star) during the period 1966–2024 on the tectonic map provided by GEM.

## 3. DEFINITION OF ANALYSIS METHODS

In this study, the statistical analyses of seismic activity are restricted to shallow earthquakes with focal depths less than 70 km. This upper depth limit was selected because the seismogenic layer is generally confined to this depth in most tectonic regions worldwide.

Analyses of seismicity, particularly those targeting precursory seismic quiescence, provide valuable insights into the occurrence of major crustal earthquakes and contribute to regional seismic hazard assessment. To investigate earthquake activity along the active tectonic fault systems of Albania, several statistical parameters were evaluated, including histograms of temporal and magnitude distributions, the fractal dimension (Dc-value), and the precursory seismic quiescence (Z-value).

### 4.1. Seismotectonic (Gutenberg-Richter relation) and Importance of Completeness Magnitude, *Mc*

The frequency-magnitude relationship proposed by Gutenberg and Richter (1944) describes the empirical power-law distribution of earthquake magnitudes and is expressed as:

$$\log_{10} N(M) = a - bM \tag{1}$$

where *N(M)* is the cumulative number of events with magnitudes greater than or equal to *M* within a given time period, whereas *a* and *b*-values are constants. In studies of frequency-magnitude distributions and precursory seismic quiescence, accurate estimation of the magnitude completeness, *Mc*- is crucial, as using the maximum number of reliable events is essential for obtaining robust results. Because *Mc*-value tends to be higher during the earlier part of a catalog—due to the limitations in detection capabilities—its temporal variation can lead to biased seismicity estimates. Variations in *Mc*-value depend on both the earthquake activity level of the region and the sensitivity and density of the seismic network. Consequently, the accuracy of the precursory seismic quiescence analyses is directly influenced by appropriate determination of the *Mc*-value.

### 4.2. Fractal Dimension (Correlation Dimension, *Dc*-value)

The fractal dimension quantifies the geometric complexity of a spatial distribution and can vary with both space and time. Fractal analysis is widely used to examine the clustering properties and size scaling characteristics of earthquake occurrences, under the assumption that earthquake distributions exhibit fractal characteristics. Such analyses are important because they describe the self-similarity and heterogeneity of seismogenic structure. Such analyses are important because they describe the self-similarity and heterogeneity of seismic structures. Among the different methods, of fractal analysis, the correlation dimension (DC)—introduces by Grassberger and Procaccia (1983) through the sphere-counting method—is one of the most commonly applied. The correlation sum *C(r)* and the correlation dimension *Dc* are defined as follows:

$$Dc = \lim_{r \to 0} \left[ \log C(r) / \log r \right] \quad (2)$$

$$C(r) = 2N_{R<r} / N(N-1) \quad (3)$$

where $C(r)$ is the correlation function, $r$ is the distance between two earthquake epicenters and $N$ is the number of earthquakes pairs separated by a distance $R<r$. The fractal dimension (Dc) is obtained by fitting a straight line to a log -log plot $C(r)$ versus $r$. The spatial and temporal fractal characteristics of seismicity provide insights into heterogeneity and complexity of fault systems (Kagan, 2007). Earthquake distributions generally conform to fractal statistics; hence variations in Dc reflect differences in the organization and clustering of seismic activity. Regions with lower Dc values typically correspond to more strongly clustered seismicity, while higher Dc values indicate more spatially uniform distributions. Fractal dimension analysis can also help identify potential seismic gaps, representing unruptured areas along fault systems that may host future earthquakes (Toksöz *et al*. 1979). Therefore, variations in Dc are directly related to the degree of structural complexity and the heterogeneity of stress accumulation within active fault regimes.

### 4.3. Process for Declustering of Earthquake Data and Standard Normal Deviate Z-Test (Precursory Seismic Quiescence, Z-Value)

Foreshocks, aftershocks, and earthquake swarms can distort the temporal distribution of seismic events, affecting statistical analyses of seismicity. To enable a quantitative assessment of rate changes in earthquake activity, dependent events must be removed from the catalog.

In this study, dependent events were identified and excluded using the Reasenberg (1985) declustering algorithm, as implemented in the ZMAP software (Wiemer, 2001). The resulting declustered catalog containing 10,278 independent earthquakes, was then used for the analysis of precursory seismic quiescence (Z-value).

A spatial grid of 0.1° × 0.1° in latitude and longitude was applied to the study area. The ZMAP method was used to detect regions exhibiting quiescence anomalies, while the standard normal deviate (Z-test) was employed to evaluate their statistical significance. This method calculates the Log Term Average, (LTA(t)), which expresses the degree of quiescence in terms s of standard deviations:

$$Z(t) = \frac{R_{all} - R_{wl}}{\sqrt{\frac{\sigma^2{}_{all}}{n_{all}} + \frac{\sigma^2{}_{wl}}{n_{wl}}}} \tag{4}$$

where $R_{wl}$ is the mean earthquake rate within the foreground window, $R_{all}$ is the average rate over the entire background period, $\sigma$ represents the standard deviations, and $n$ is the number of samples, within and outside the window, respectively. The $Z$-value is estimated as a function of time by allowing the foreground window slide along the catalogue's time series. The resulting time dependent function, denoted LTA ($t$), enables the detection of periods of seismic quiescence that may precede large earthquake events.

## 4. Results of Statistical Investigations of Recent Seismicity and Discussions

A statistical evaluation of recent earthquake activity along the active tectonic fault systems of Albania was conducted basing on the fractal dimension (Dc-value), the standard normal deviate (Z-value), and regional, temporal, and magnitude histograms covering the period 1964–2024. The fractal dimension provides insight into the complexity and clustering patterns of earthquake occurrences, while the Z-helps detecting precursory seismic quiescence anomalies prior to major shocks. Together, these parameters provide important perspectives for assessing future seismic hazards in the region. Figure 3a presents the cumulative number of earthquakes over time for both the original and declustered catalogs. Between 1966 and 1975, seismicity remained relatively stable, followed by only a few events from 1975 to 1979. A notable increase in earthquake activity occurred between 1979 and 1995 and continued through 2019, with a significant rise in the number of events observed between 2019 and 2023.Figure 3b illustrates the temporal variation of the magnitude of completeness (Mc-value). The original catalog comprises 38,816 earthquakes with $M_L \geq 0.1$. As noted earlier, the magnitude of completeness (*Mc*-value) is a critical parameter for analyzing precursory seismic quiescence. Accordingly, *Mc* was estimated as a function of time using the maximum curvature method within a moving-window approach. Specifically, *Mc*-values were calculated for samples of 2000 earthquakes per window. Because *Mc* exhibits temporal variability, the number of events per window was maximized to ensure robust statistical evaluations (Fig. 3b). Temporal variations in *Mc* were further examined using standard deviations computed over 100-event moving windows. Mc remained between 2.5 and 3.4 until 2019, after which it decreased to approximately 2.5 by the end of that year. Between 2019 and 2023, *Mc* fluctuated within the range 1.5–2.8. Over the longer interval of 1967–2019, Mc varied significantly between 2.5 and 3.5. Based on these findings, an average *Mc*-value of 2.8 was adopted for all subsequent statistical analyses.

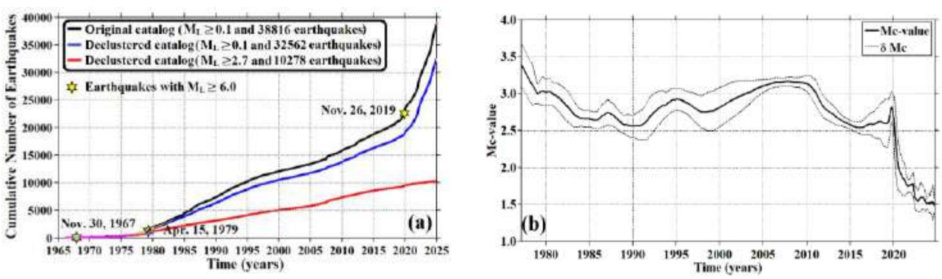


**Fig. 3: (a)** Time variations of the cumulative number of earthquakes between 1966 and 2024 for the catalog with $M_L \geq 0.1$ and the declustered catalog with $Mc \geq 2.7$. **(b)** Temporal variation of magnitude completeness (Mc-value). The standard deviation, δMc, is also indicated.

As described in the *Data* section, the earthquake catalog comprises events with magnitudes ranging from 0.1 to 6.9, with the largest event corresponding to the 1979 Ulqin earthquake ($M_L = 6.9$). Accordingly, a value of ML = 7.0 was selected as the upper limit for the magnitude axis. A key outcome of the declustering process is the removal of dependent events, resulting in a more reliable, robust, and homogeneous dataset.

Figure 4a presents the time histograms of seismic events in Albania and its surrounding regions for the period 1966 to 2024. Seismic activity remained relatively low between 1966 and 1974, with only 329 recorded events. Between 1975 and 2002, earthquake occurrences increased substantially, reaching a total of 12,537 events, followed by 8,327 events between 2003 to 2018. A pronounced increase is observed after 2018, with 17,640 earthquakes recorded during the period 2019-2024.

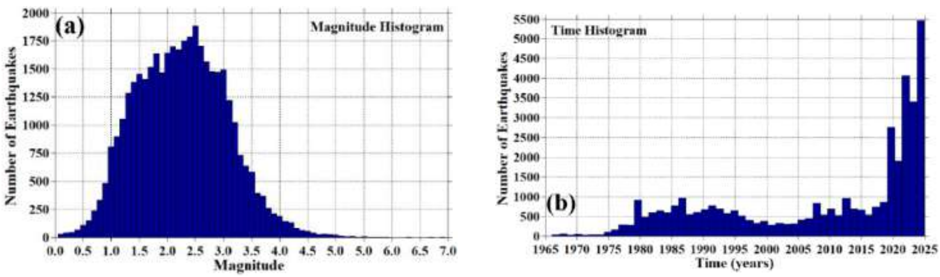


**Fig. 4: (a)** Time histogram of seismicity in Albania and its surroundings from 1966 to 2024. **(b)** Magnitude histogram.

Figure 4b presents the magnitude histogram of seismic events within and around the Albanian fault zones. As noted in the Data section, earthquake magnitudes range from 0.1 to 6.9, with the frequency of events exhibiting a typical exponential decline as magnitude increases.

Most earthquakes have magnitudes between 1.0 and 3.5, with the highest frequency at ML = 2.5. Specifically, 31,062 earthquakes fall within the range $0.1 \leq ML < 3.0$, 6,912 events within $3.0 \leq ML < 4.0$, 777 events within $4.0 \leq ML < 5.0$, 62 events within $5.0 \leq ML < 6.0$, and only 3 events within $ML \geq 6.0$. These results indicate that small-to-moderate earthquakes (ML 1.0–3.5) occur far more frequently than larger events in Albania and its surroundings. The high frequency of small earthquakes may reflect increasing stress accumulation along the Eastern Fault Zones (EFZ) in recent years.

The correlation dimension (*Dc*-value) of earthquake epicenter distributions within Albania's active tectonic fault systems was then calculated by fitting a straight line to the curve of the correlation integral, C(R), versus distance, R. *Dc*-values were determined with 95% confidence limits using linear regression (Fig. 5). For the entire study region, the Dc-value was found to be $Dc = 1.93 \pm 0.04$, with a well-defined linear scaling range between 5.02 and 208.21 km (Fig. 5). Standard deviations of Dc-values were also estimated within this distance range. As previously discussed, the fractal dimension provides valuable insight into the spatial organization of seismicity, since earthquake distributions typically exhibit fractal characteristics. Higher *Dc*-values are generally associated with active and structurally complex fault systems (Öncel and Wilson, 2002), whereas lower values characterize regions where earthquakes are clustered due to isolated asperity failures (Barton *et al*. 1999). Therefore, the relatively high *Dc*-values observed in this study likely reflect the dominant structural properties of the Albanian fault systems and the clustering of seismic activity. Because a uniform distribution decreases with increasing clustering, these high *Dc*-values may also indicate spatial variations in stress distribution across the region.

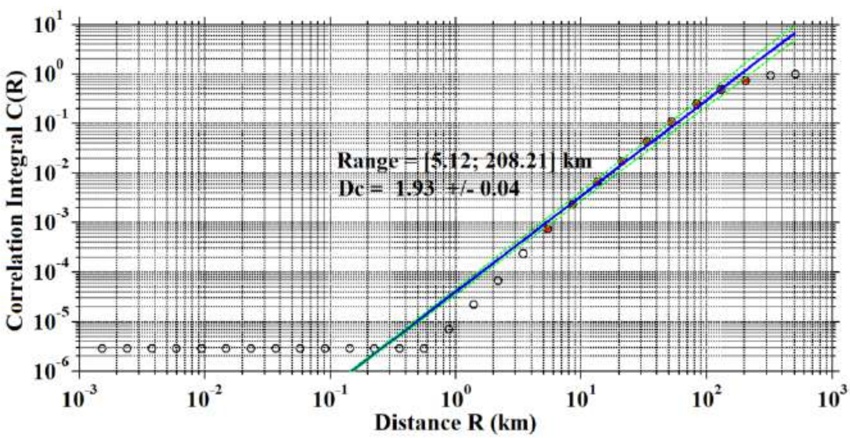


**Fig. 5:** Fractal dimension (Dc-values) for the Albanian fault zones. The slope of the blue line represents Dc-values. Dashed lines indicate standard deviations.

As shown in Figure 6, the regional variations of the standard normal deviate (Z-value) along Albania's active tectonic fault systems are mapped for early 2025. The interpretation of Z-values is straightforward: low Z-values indicate statistically insignificant changes in earthquake activity, whereas high Z-values correspond to a reduction in seismicity rate, often interpreted as precursory quiescence.

When compared with earlier studies (e.g., Öztürk and Bayrak, 2012; Öncel & Wilson, 2007; Award *et al*. 2005), the patterns obtained here are consistent with the general observation that quiescent periods may precede major seismic events in regions of high strain accumulation. However, the present analysis extends these interpretations by providing a quantitative spatial mapping of Z-value anomalies within the specific tectonic framework of Albania.

The regional distribution of Z-values for the Albanian fault systems is presented in Figure 6. Seven anomalous regions (A–G) exhibiting significant seismic quiescence were identified:

**A:** Shkodër–Bajram Curri transversal fault zone, northern Albania (42.00°N, 19.50°E – 42.35°N, 20.10°E), encompassing the Curraj i Epërm–Rragam–Theth fault zone.

**B:** Skavica–Kukës–Prizren transversal fault segment, part of the Kurbnesh–Kukës–Prizren fault zone, northeastern Albania, extending into Kosovo (41.90°N, 20.35°E – 42.25°N, 20.70°E).

**C:** Cerje–Prespa–Bitola fault zone, extending into North Macedonia near the Albanian border (40.75°N, 20.95°E – 41.00°N, 21.25°E).

**D:** Elbasan–Bene–Kostenj fault segment, central portion of the Vlora–Lushnje–Elbasan transversal fault zone (41.10°N, 20.10°E – 41.35°N, 20.30°E).

**E:** Vjosa River estuary–Fier–Lushnjë fault segment, southern portion of the Vlora–Lushnje–Elbasan transversal fault zone (40.65°N, 19.30°E – 40.90°N, 19.70°E).

**F:** Kudhes–Kuç–Vermik fault zone (40.10°N, 19.80°E – 40.30°N, 19.75°E).

**G:** Selo–Dhrovjan–Lazarat fault segment, part of the Selo–Rabie fault zone, including the Libohovë–Poliçan zone (39.85°N, 20.35°E – 39.95°N, 20.45°E; 40.00°N, 20.25°E – 40.10°N, 20.35°E).

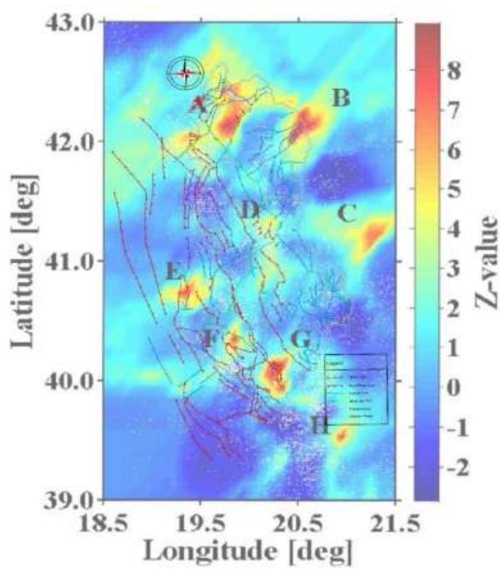


**Fig. 6:** Changes in Z-values at the beginning of 2025 (Tw = 4.5 years) for the updated active tectonic fault systems map of Albania. White dots represent declustered events with $M_L$ > 2.7.

Previous studies (Katsumata and Kasahara, 1999; Chouliaras and Stavrakakis, 2000; Polat *et al*. 2008; Öztürk, 2013; Öztürk and Bayrak, 2012; Ormeni *et al*. 2017; Öztürk and Ormeni, 2021) have demonstrated that seismic quiescence often precedes major earthquakes in various parts of the world. Therefore, the quiescence anomalies observed in different segments of Albania's active fault systems may be significant and could potentially indicate the locations of future large earthquakes.

Using the maximum likelihood approach to estimate the LTA(t) function to map *Z*-values, these studies showed that regions with larger *Z*-values can be interpreted as potential nucleation zones for forthcoming major earthquakes. Similar methodologies were applied by, Polat *et al.* (2008), Öztürk (2011), Öztürk and Bayrak (2012), and later by Ormeni and Öztürk (2017; 2024), Öztürk and Ormeni (2021) to various tectonic regions of Turkey and Albania, yielding meaningful results. For instance, significant seismic quiescence anomalies were detected before the 8 March 2010 Elazığ and 23 October 2011 Van earthquakes in eastern Turkey, as well as prior to the 26 November 2019 Durrës earthquake in western Albania These findings confirm that these statistical parameters can play an important role in identifying potential sites of future seismic activity. In summary, the combined analysis of *Dc*-value and *Z*-value provides a robust framework for seismic hazard assessment. The identification of high *Dc*-values and pronounced quiescence anomalies in several regions of Albania at the beginning of 2025 suggests that these anomalous zones warrant special attention in the evaluation of earthquake potential along the country's active tectonic fault systems.

## 5. CONCLUSIONS

This study presents a temporal and regional statistical analysis of recent earthquake activity along Albania's active tectonic fault systems. Several key parameters were applied—namely, the correlation dimension (Dc-value), precursory seismic quiescence (Z-value), and regional, temporal, and magnitude histograms—to evaluate earthquake clustering patterns and seismic hazard potential. The overall Dc-value of 1.96 indicates significant clustering of earthquake activity at both small and large spatial scales.

The Z-value mapping for 2025 revealed several notable quiescence anomalies distributed across seven regions (A–G) along Albania's active fault systems, including the Shkodër–Bajram Curri, Skavica–Kukës–

Prizren, central and southwestern segments of the Vlora–Lushnje–Elbasan fault zone (VLED), Kudhes–Kuç–Vermik, Selo–Dhrovjan, Libohovë–Poliçan fault zones, and the Cerje–Prespa–Bitola fault zone near the Albanian border.

The integrated application of Dc-value and Z-value provides valuable insight into earthquake clustering, stress accumulation and potential future seismic activity. The observed quiescence anomalies, in combination with the statistical characteristics of the earthquake distributions, contribute to the improving seismic hazard assessment and may help forecast the probable locations of the earthquakes in Albania's most active tectonic regions.

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**Declarations**

**Data accessibility (websites, platforms):** www.geo.edu.al, EMSC-CSEM.org

**Declaration of AI use:** There has been no use of AI when writing the actual paper.

**Author Contributions**

RrO – Conceptualization; compilation and cleaning of the earthquake catalogue; tectonic interpretation; writing – original draft preparation; writing – review & editing; coordination of the Albania-focused seismotectonic framework; SÖ– Gümüşhane University, Department of Geophysics, Türkiye Methodology; statistical analysis; ZMAP processing; fractal dimension and Z-valueanalysis; validation; writing – methodology section; LP –Tectonic framework evaluation; interpretation of active fault systems; integration of neotectonic models; critical revision of geological sections, IH –Data processing; spatial analysis of epicentral distributions; preparation of tectonic and seismotectonic maps; EV-Expert evaluation of structural geology; review of tectonic map interpretations; integration of regional fault kinematics; PDiM–Review of geologic data consistency; contribution to the interpretation of crustal deformation and fault segmentation; NP –Contribution to regional seismicity assessment in northeastern Albania and Kosovo; catalog cross-checking; revision of temporal analyses; DM and OGj- Technical support; dataset verification; GIS preparation of maps; assistance in visualization and figure design

**Authors' approval:** All the authors have approved the final version of the manuscript

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**REFERENCES**

**Aliaj Sh, Koçiu S, Muço B, Sulstarova E. 2010.** *Seismicity, seismotectonic and seismic hazard assessment in Albania*. Albanian Academy of Sciences.

**Awad H, Mekkavi M, Hassib, G, Elbohoty M. 2005.** Temporal and three-dimensionalspatial analysis of seismicity in the Lake Aswan area, Egypt. *Acta Geophysica Polonica,* **53(2):** 152–166.

**Barton DJ, Foulger GR, Henderson JR, Julian BR. 1999.** Frequency-magnitude statistics and spatial correlation dimensions of earthquakes at Long Valley Caldera, California. *Geophysical Journal International,* **138**: 563–570. https://doi.org/10.1046/j.1365- 246X.1999.00898.x.

**Grassberger P, Procaccia I. 1983.** Measuring the strangeness of strange attractors. *Physica,* **9(1-2):** 189–208. https://doi.org/10.1016/0167-2789(83)90298-1.

**Gutenberg R, Richter CF. 1944.** Frequency of earthquakes in California. *Bulletin of the Seismological Society of America,* **34 (4):** 185–188. https://doi.org/10.1785/BSSA0340040185

**Habermann, R. E. (1983).** Teleseismic detection in the Aleutian Island arc. *Journal of Geophysical Research,* **88(B6):** 5056–5064. https://doi.org/10.1029/JB088iB06p05056.

**Hirata T. 1989.** Correlation between the b-value and the fractal dimension of earthquakes.*Journal of Geophysical Research,* **94**: 7507–7514. https://doi.org/10.1029/JB094iB06p07507.

**Kagan YY. 2007.** Earthquake spatial distribution: the correlation dimension. *Geophysical Journal International,* **168**: 1175–1194. https://doi.org/10.1111/j.1365-246X.2006.03251.x.

**Katsumata K, Kasahara M. 1999.** Precursory seismic quiescence before the 1994 Kurile earthquake (Mw = 8.3) revealed by three independent seismic catalogs. *Pure and Applied Geophysics,* **155(2–4)**: 443–470. https://doi.org/10.1007/s000240050274.

**Mandelbrot BB. 1982.** *The fractal geometry of nature*. Freeman Press, San Francisco.

**Melo V. 1986.** *The structural geology and geotectonic (The geology of the Albanides)* [In Albanian]. University of Tirana.

**Mogi K. 1962.** Magnitude-frequency relation for elastic shocks accompanying fractures of various materials and some related problems in earthquakes. *Bulletin of the Earthquake Research Institute, Tokyo University, 40*, 831–853.

**Ormeni Rr, Koçiaj S, Fundo A, Daja SH, Doda V. 2013.** Moderate earthquakes in Albania during 2009 and their associated seismogenic zones. *Italian Journal of Geosciences,* **132(2):** 203–212. https://doi.org/10.3301/IJG.2012.45.

**Ormeni Rr, Öztürk S, Fundo A., & Kemal, Ç. (2017).** Spatial and temporal analysis of recent seismicity in different parts of the Vlora-Lushnja-Elbasani-Dibra Transversal Fault Zone, Albania. *Austrian Journal of Earth Sciences, International Journal of the Austrian Geological Society*.

**Ormeni Rr,, Gjuzi O, Bozo R,, Muci D, Dushi I, Minarolli A, Selmani I.2021**. Some main aspects of Albanian seismicity during two decades of this century. Symposium *Geosciences, Achievments and Future Challenges*. November 25, 2021, IGEO, PUT

**Ormeni Rr, Öztürk S, Hasimi A, Silo E, Elvin Como E.2023**.Region-time-magnitude analysis of earthquakes activity in the Elbasani geothermal zone, Albania. 23rd International Multidisciplinary Scientific GeoConference SGEM, 1 - 10 July, 2023, Albena Resort & Spa, Bulgaria. (BE) https://www.sgem.org/

**OrmeniRr, Öztürk S, 2024.** The earthquake of November 26, 2019 and what can we learn" Published by: Academy of Sciences of Albania. ISBN: 9789928809476. Printed by: Filara Tirana 2024.

**Öncel AO, Wilson TH. 2007.** Anomalous seismicity preceding the 1999 Izmit event, NW Turkey. *Geophysical Journal International*. https://doi.org/10.1111/j.1365- 246X.2006.03298.x.

**Öztürk S, Bayrak Y. 2012.** Spatial variations of precursory seismic quiescence observed in recent years in the eastern part of Turkey. *Acta Geophysica,* **60(1):** 92–118. https://doi.org/10.2478/s11600-011-0035-z.

**Öztürk S. 2013.** A statistical assessment of current seismic quiescence along the North Anatolian Fault Zone: Earthquake precursors. *Austrian Journal of Earth Sciences,* **106(2)**: 4–17.

**Öztürk S, Ormeni Rr. 2021.** A comprehensive spatiotemporal evaluation of the current earthquake activity in different parts of the Frakull-Durrës fault zone, Albania. *BALTICA,* ***34*****(1),** 58–70. Doi https://doi.org/10.5200/baltica.2021.1.5.

**Polat O, Gok E, & Yılmaz D. 2008.** Earthquake hazard of the Aegean Extension region (West Turkey). *Turkish Journal of Earth Sciences,* **17 (3)**: 593–614. https://journals.tubitak.gov.tr/cgi/viewcontent.cgi?article=1541&context=earth.

**Reasenberg, PA. 1985.** Second-order moment of Central California seismicity, 1969–1982. J*ournal of Geophysical Research,* **90(B7),** 5479–5495. https://doi.org/10.1029/JB090iB07p05479.

**Roy S, Ghosh U, Hazra S, Kayal JR. 2011.** Fractal dimension and b-value mapping in the Andaman-Sumatra subduction zone. *Natural Hazards,* **57**: 27–37. https://doi.org/10.1007/s11069-010-9667-6.

**Sulstarova E, Koçiaj S, Aliaj SH. 1980.** *Seismic regionalization of Albania*. Science Academy of Albania, Tirane.

**Toksöz MN, Shakal AF, Michael A.J. 1979.** Space-time migration of earthquakes along the North Anatolian Fault Zone and seismic gaps. *Pure and Applied Geophysics,* **117**, 1258–1270. https://doi.org/10.1007/BF00876218.

**Utsu T. 1971.** Aftershock and earthquake statistic (III): Analyses of the distribution of earthquakes in magnitude, time and space with special consideration to clustering characteristics of earthquake occurrence (1). *Journal of Faculty of Science, Hokkaido University,* **Series VII (Geophysics), 3:** 379–441.

**Wiemer S, Wyss M. 2000.** Minimum magnitude of completeness in earthquake catalogs: Examples from Alaska, the Western United States, and Japan. *Bulletin of the Seismological Society of America,* **90(3):** 859–869. https://doi.org/10.1785/0119990114.

**Wiemer S. 2001.** A software package to analyze seismicity: ZMAP. *Seismological Research Letters,* **72(2):** 373–382. https://doi.org/10.1785/gssrl.72.3.373.