

## SERIES OF EARTHQUAKES FROM THE BORDER EPICENTRAL AREA BITOLA-FLORINA IN JANUARY 2022

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### ABSTRACT

The seismic activity in the border epicentral area Bitola-Florina is characterized by relatively frequent and high autochthonous seismic activity. Spatially extended in the southwestern part of the Republic of North Macedonia and the northern part of the Republic of Greece, seismicity is studied mutually within the common seismotectonic conditions. The intense activity of tectonic processes and the dynamics of the tectonic structure, conditions asymmetric differential tectonic movements, which results with the occurrence of an earthquake.

The series of earthquakes in the border epicentral area Bitola-Florina starts with the earthquake on January 9, 2022, at 21h 43min (UTC) with local Richter magnitude  $M_L = 5.6$  and intensity  $I = V-VI$  degrees according to the European Macroseismic Scale (EMG-1998). Results of the seismological research - the overall spatial distribution of the epicenters of the earthquakes is related to the system of faults that have longitudinal stretches along the eastern parts of Mount Pelister, Bitola fault and Porecko-Krushevo fault. The detailed study of the seismic activity in the border epicentral area Bitola-Florina is in function of better understanding of the processes that generate earthquakes and their action and consequences on the environment.

**Keywords:** epicenter, earthquake, fault

### INTRODUCTION

The total number of earthquakes considered temporally and spatially, define the seismic regime of the epicentral area Bitola-Florina. The tectonic structure of the border epicentral area Bitola-Florina, conditions asymmetric differential tectonic movements between the Pelister horst and the Pelagonian depression, which are the main features for defining the considered area, and is manifested by characteristic seismic activity, in terms of the connection of the earthquake with the fault dislocations.

Neotectonic fault dislocations that belong to the border epicentral area Bitola-Florina and are characterized by certain seismic activity are: Bitola fault, Porecko-Krushevo fault and a small part of the southern wing of the Mukoski fault. We are interested in the Bitola and Porecko-Krushevo faults around which the epicenters of the series of earthquakes are spatially located.

The series began with the earthquake on January 9, 2022, at 21h 43min (UTC) with local Richter magnitude  $M_L = 5.6$  and intensity  $I = V-VI$  degrees according to EMS-98. Spatially, the

epicenter of the earthquake is on the territory of R. Greece but the macroseismic effects were strongly felt on the territory of the Republic of N. Macedonia.

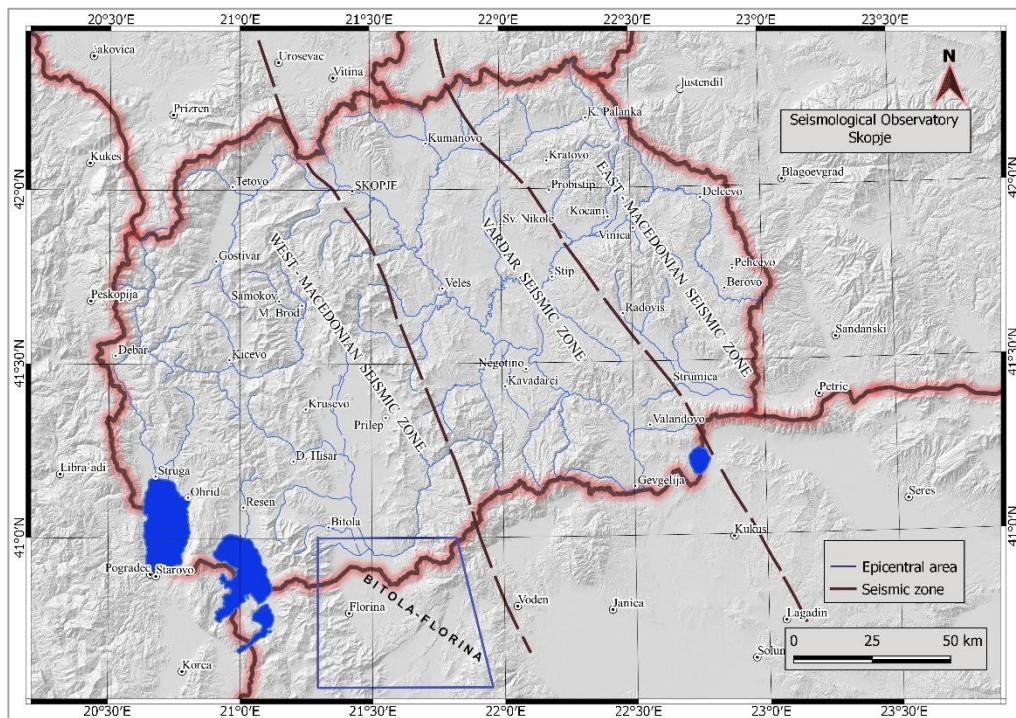
## **BASIC CHARACTERISTICS OF THE SEISMICITY OF THE REPUBLIC OF NORTH MACEDONIA AND THE BORDER AREA**

The region that covers the territory of the Republic of North Macedonia and its border area, in tectonic terms, is one of the eastern parts of the Mediterranean orogenic zone of the Alpine-Himalayan orogenic belt. The Mediterranean area has a high seismic activity - a consequence of the dynamics at the time of permanent collision between the three major tectonic plates: Eurasian, Arabian and African. According to numerous seismological research, the observed historical and modern seismic activity on the territory of Macedonia and the border areas is mainly tectonic, with the exception of a number of weak urvins earthquakes. As a result of the various phases in the geological history, the faults on the territory of Macedonia and the border areas are oriented approximately along the north-south direction, the so-called longitudinal faults, and approximately along the east-west direction, the so-called transverse faults. Their intersection leads to the appearance of tectonic nodes that are carriers of high seismic energy, as they are either sources of strong autochthonous earthquakes or zones of abnormal seismic energy absorption from distant earthquakes.

The seismic activity on the territory of Macedonia and the border areas is characterized by the distribution, namely the concentration of earthquakes in three main seismic zones, which extend longitudinally (i.e. approximately along the north-south direction), Figure 1:

- West-Macedonian seismic zone,
- Vardar seismic zone,
- East-Macedonian seismic zone.

These zones also cover parts of R. Albania, R. Greece, R. Bulgaria, R. Kosovo and R. Serbia. On the territory of Macedonia and the border areas, there are three secondary seismic zones, transverse to the upper three main ones. These zones are determined by the directions: Kyustendil (R. Bulgaria) - Skopje - Debar, Pehchevo - Veles - Ohrid, Sandanski (R. Bulgaria) - Valandovo - Korca (R. Albania). The connection between the observed seismicity and the tectonic characteristics on the territory of Macedonia and the border areas gives the seismotectonic characteristics according to which within the seismic zones there are parts where the epicenters of the earthquakes are concentrated - epicentral areas.



**Figure 1.** Main seismogenic zones and border epicentral areas Bitola-Florina on the territory of R. N. Macedonia.

The intersections of the main and secondary seismic zones are areas of high seismic activity, in which the strongest earthquakes occur both on the territory of Macedonia and in the border areas.

In each of the seismic zones on the territory of the Republic of N. Macedonia and its border areas, there is a certain regularity of the release and attenuation of seismic energy, as well as a particular distribution of the hypocenters of earthquakes. However, in all seismic zones, the shallow distribution of the hypocenters of earthquakes prevails, from 10km to 30km, and most often from 10km to 20km, which indicates that the seismicity is associated with deformations in the upper parts of the lithosphere, namely the destruction of the Earth's crust.

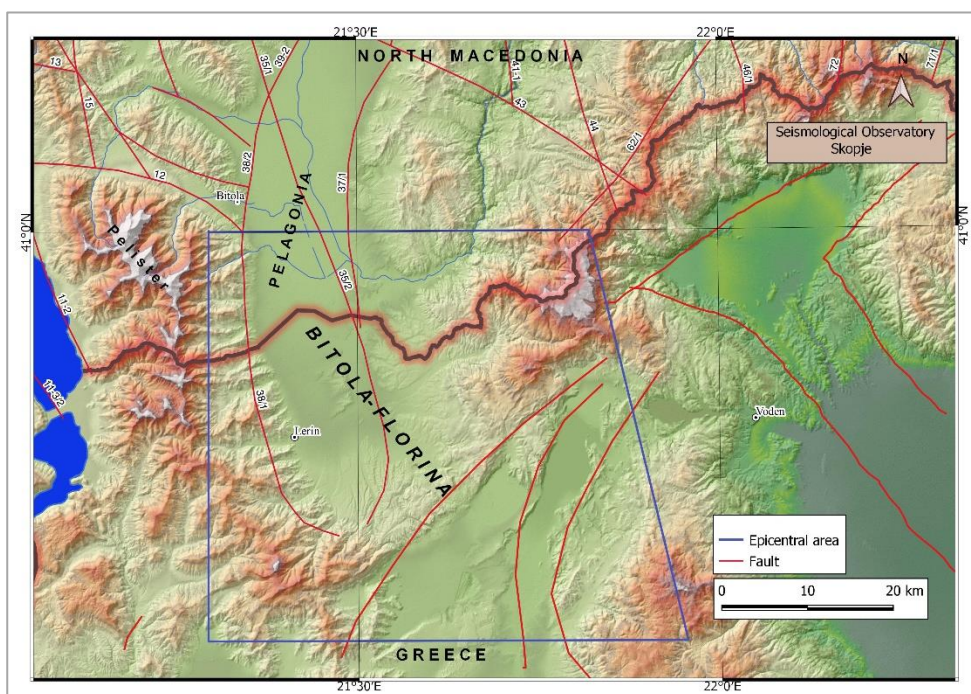
### **EARTHQUAKE SERIES IN THE BORDER EPICENTRAL AREA BITOLA-LERIN IN JANUARY 2022**

The continuous seismic activity in the long period of monitoring of the border epicentral area Bitola-Florina is of special interest in the research of modern and expected seismicity. According to the data available to the Seismological Observatory, this border epicentral area is characterized by high seismic activity, in which moderate earthquakes often occur with Richter magnitudes  $M_L \geq 4.0$ . The hypocenters of earthquakes are in the Earth's crust, with distribution from 10 km to 20 km. The seismic activity in the border area Bitola-Florina is due to the activity of the fault

dislocations: Bitola fault and Porecko - Krushevo fault around which the epicenters of the series are spatially distributed.

At the southwestern edge of the Pelagonian Depression, towards the mountain massif Pelister, the Bitola fault (no. 38) manifests itself in contrast, along which, as a result of differential movements, the western wing (Pelister) is raised and the eastern wing is lowered. The fault is seismically active and belongs to the Pelagonija group of faults. Part of this seismically active fault extends on the territory of R. Greece.

The Porecko-Krushevo fault (no. 35) is a pre-neotectonic longitudinal regional dislocation that is not evenly expressed everywhere in the relief, i.e. it appears only with its individual segments - such is the segment of about 70km along the western end of the Pelagonija and Porecka Depression. The southern part of this dislocation is in R. Greece, determined by geophysical methods, it belongs to the Pelagonija group of faults, Figure 2.



**Figure 2.** Seismotectonic map of the border epicentral area Bitola-Florina.

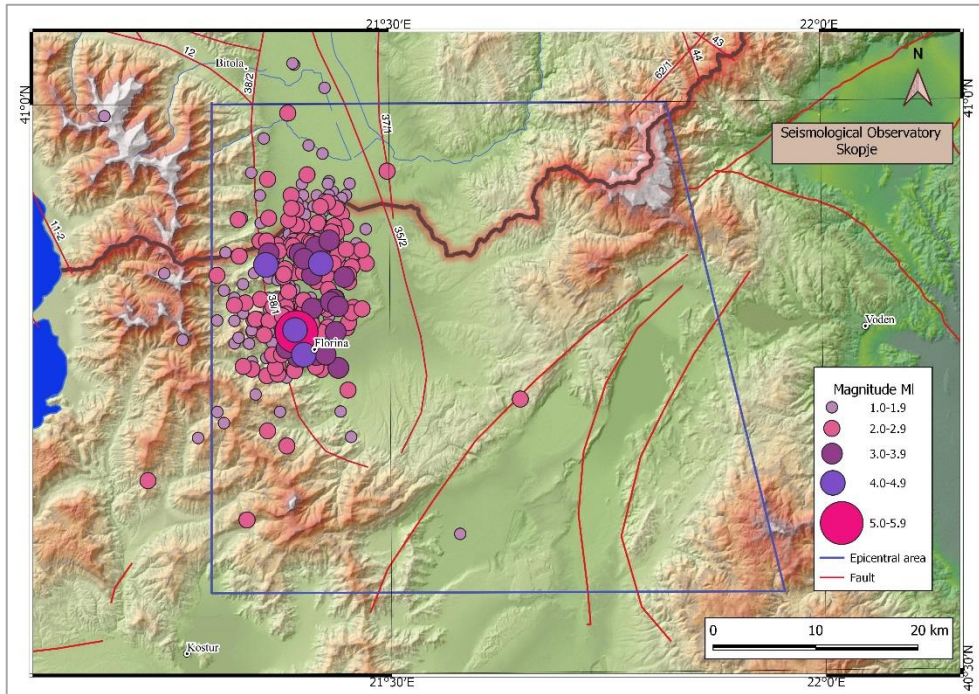
The series of earthquakes in the considered border epicentral area, starts with the earthquake on January 9, 2022, at 21h 43min (UTC) with local Richter magnitude  $M_L = 5.6$ , intensity  $I = V-VI$  degrees according to the European macroseismic scale (EMS-98) with epicenter in R. Greece. The earthquake was registered by the seismological stations on the territory of Macedonia, and the macroseismic effects were strongly felt especially in the southern parts, causing great anxiety among the citizens, but also slight damage of grade 1 in some buildings of class A and B of seismic vulnerability (masonry buildings) and some class C buildings with grade 1 seismic damage (reinforced concrete structures), Figure 3.





**Figure 3.** Damage caused by the earthquake on January 9, 2022 at 21h 43min (UTC) with local Richter magnitude  $M_L = 5.6$ , intensity  $I = V-VI$  degrees according to the European Macroseismic Scale (EMS-98).

The spatial distribution of the epicenters of the earthquakes as well as the certain focal mechanisms of the earthquakes, according to seismological and seismotectonic research, indicate the activity of the southern wing of the Bitola fault, part which belongs to the territory of R. Greece. The migration of the epicenters and their spatial distribution, indicates a certain weak seismic activity  $1.0 \leq M_L < 2.0$  on the northern wing of this fault that extends on the territory of R. N. Macedonia. The distribution of the epicenters of the earthquakes from the series in the considered area is presented on the epicenter map Figure 4.



**Figure 4.** Epicenter map of the earthquakes in the considered border epicenter area Bitola-Florina.

In the border epicentral area, in the period 9.01.2022 - 15.02.2022, a total of 306 earthquakes were registered, with the largest number of earthquakes with magnitude  $1.0 \leq M_L < 3.0$  total 277, followed by the number of earthquakes with magnitude  $3.0 \leq M_L < 5.0$ , total 28. In the series, only one moderately strong earthquake occurred with local Richter magnitude  $M_L = 5.6$ . The greatest seismic activity is observed until January 25, 2022, which indicates that most of the accumulated seismic energy is released by the strong earthquake and that there is a decline of seismic energy. Figure 5 shows the distribution of earthquakes from the Bitola-Florina area at a magnitude interval of one degree on the Richter scale. There is an obvious decrease in the number of earthquakes with the increasing of the magnitude, with the exception of earthquakes with local Richter magnitude  $1.0 \leq M_L < 3.0$ , which number is dominant.

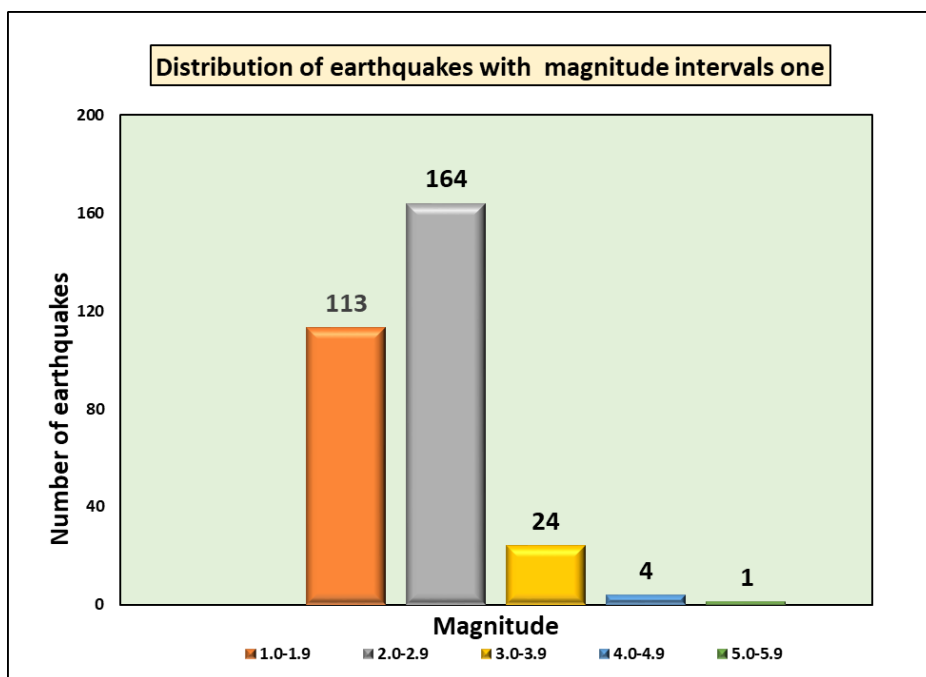


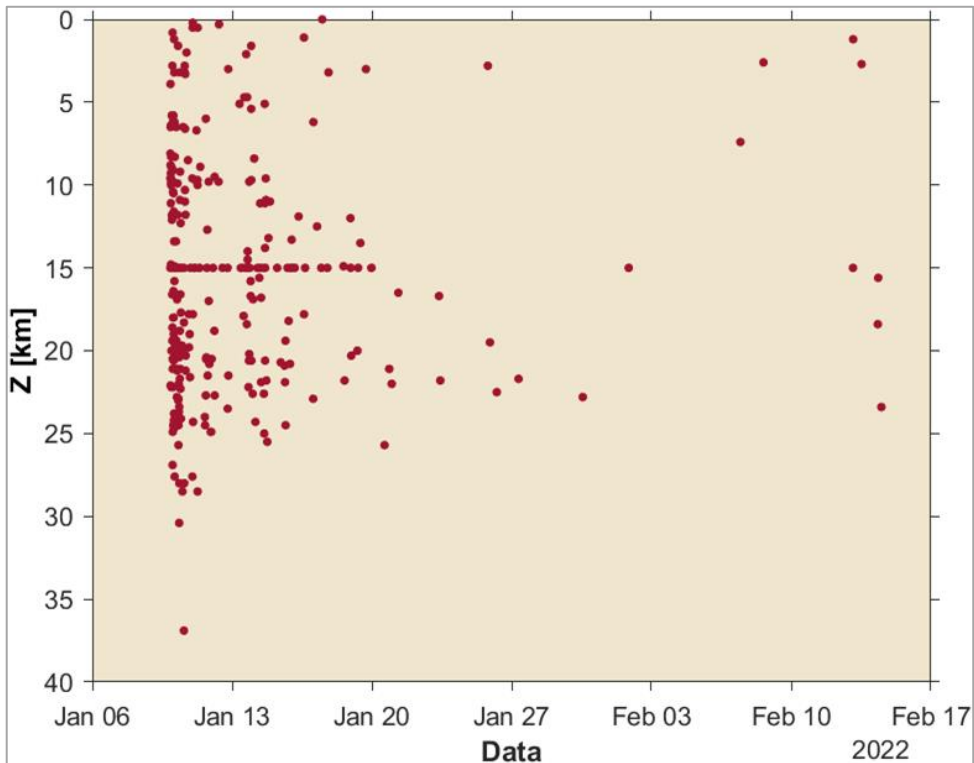
Figure 5. Distribution of the earthquakes that occurred in the border area Bitola-Florina at a magnitude interval of one degree.

Table 1 shows the earthquakes with local Richter magnitudes  $M_L \geq 4.0$  and their corresponding intensities determined according to the macroseismic effects.

Table 1. The strongest earthquakes from the series in the epicentral area Bitola-Florina

Year	Month	Day	h:min:s	$\varphi$	$\lambda$	h(km)	$M_L$	I
2022	01	09	21:43:46	40.80	21.38	21.9	5.6	V-VI
2022	01	09	21:53:20	40.86	21.42	15.0	4.3	IV
2022	01	09	23:38:26	40.78	21.40	11.8	4.0	IV
2022	01	11	15:14:30	40.86	21.36	24.0	4.4	V
2022	01	11	17:44:08	40.80	21.39	15.0	4.3	IV

The average hypocenter depth is concentrated in the upper limit of the Earth's crust (Moho discontinuity) within the interval from 10km to 20km, which indicates earthquakes with pronounced shallow hypocenters, Figure 6. Earthquake epicenters are concentrated in a zone and their projection on the Earth's surface extends in a northwest-southeast direction. The shallow depths of the hypocenters of earthquakes have significant macroseismic effects on the entire border epicentral area.



**Figure 6.** Spatial distribution of the hypocenters of the earthquakes in the considered border epicentral area Bitola-Florina.

The process of releasing energy during a series that has shallow seismic sources shows a multiple character (cumulative seismic shocks), which leads to the amplification of energy at close distances due to seismic superposition of seismic waves from individual seismic shocks.

The three seismic shocks that occurred one after the other on January 9, 2022 in a relatively short time interval, with magnitudes  $M_L = 5.6$ ,  $M_L = 4.3$ ,  $M_L = 4.0$ , can be given as an example. Their epicenters migrate in a northwest direction, so the macroseismic effects are more pronounced in that direction. The geology of the considered area has a great influence on all the above.

## **CONCLUSION**

According to the previous observations of the Seismological Observatory at the Faculty of Natural Sciences and Mathematics in Skopje, the border epicentral area Bitola-Florina is characterized by moderate seismic activity. For the Bitola-Florina area, the spatial distribution of the epicenters of most of the earthquakes in the series, are along the Bitola fault, which means they are generated from this fault. Confirmation of the activity of this fault is also determined by the focal mechanism solutions of fault planes that coincide with the fault plane of the above named fault.



Macroseismic effects of earthquakes with epicenters on the territory of R. Greece, depending on the seismotectonic conditions and the geology of the area under consideration, have significant effects on the territory of Macedonia. Therefore, through the total number of registered earthquakes in the series, the main parameters of seismicity are obtained, which are the basis of seismic zoning as an important part of the complex problem of forecasting future seismic activity - separation of areas with maximum intensity of macroseismic action. The detailed study of the seismic activity in this border area is in function of better understanding of the processes that generate earthquakes and their action and consequences on the environment.

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