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Basic Aspects of Seismic Activity in Albania and Its Surrounding Area During 2018 Year

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Abstract: The Albanian orogeny, as the most south-western part of the Euro-Asiatic plate, in convergence with the Adria microplate. The main cause of Albanian seismicity is the collision of Adria microplate with the Albanian orogeny. Seismic phases recorded by the Albanian network, integrated with data of Thessalonica (Greece), Montenegro and INGV (Italy) MSO (Montenegro) and MEDNET networks, are used to prepare the database for this year. On that territory 39.0-43.0N-18.5-21.5E, 780 earthquakes were located with running magnitude 1.0 to 5.1Richter. About 14 earthquakes were felt by population of Albania. In this year some of seismic zones are more active: 1) The Vlora-Lushnje-Elbasan transversal fault zone had generated 72 earthquakes with ranging magnitude 1.0 to 3.9 Richter. 2) In the Himara-Borshi- Kardhiq seismogenic zone, there are faults and flexures, expressed also with contrasts in relief. In this fault zone were located 108 earthquakes with ranging magnitude 1.2 to 4.5 Richter and maximum depth 10 km. 3) The Kurbnesh-Skavica seismogenic zone lies in the area of inner Albanides, along a depression zone of faults extending nearly meridional and relatively narrow. There were located 23 earthquakes with ranging magnitude 1.2 to 3.7 Richter. 4) Significant increase of seismic activity was registered on both sides of Albania and Greece border territory. 5) Highest increased of seismic activity was registered in central Albania expressed by sequences of moderate earthquake of Gjiri Lalzit (Durresi) M_L5.1 occurred at July 4, and by sequences of moderate earthquake of Vinjolla (Bulqiza) earthquake M_L5.1 occurred at August 11. 6) Significant increase of seismic activity was registered in north and northwest Albania border on the Montenegro territory. Two moderate earthquake respectively: the first occurred in Plava M = 4.6 (Richter) on 4 January 2018 and the second occurred in Ulqini M = 4.6 (Richter) on 13 November 2018.

Key words: earthquake, seismicity, aftershocks, fault

1. Introduction

Albania is situated in Alpine-Mediterranean seismic belt comprising the zone of contact between lithosphere plates of Africa and Eurasia. The Albanian orogeny, as the most south-western part of the Euro-Asiatic plate, in convergence with the Adria micro plate, is divided in two areas with different tectonic regimes: the external area with compressive regime, representing its offshore part and the internal area with expanding regime, representing the continental area [1, 2]. The main geological structures found within the Albanian territory are called the Albanides, which are part of the Dinaric-Albanid-Hellenic arc of the Alpine orogeny. The main cause of Albanian seismicity is the collision of Adria microplate with the Albanian orogeny. This collision not only directly influences the activation of longitudinal faults on the edges of the orogeny and on the segments of transversal faults cutting through this contact but has a tectonic implication even on the inner part of the country, on the longitudinal and transverse faults cutting across the eastern and north-eastern part of Albania [3, 4]. Albania is characterized by intense micro seismic activity and small and medium-size earthquakes and only seldom by large event. The Albanian region historically is stroked by strong earthquakes (Io = VIII EMS-98), as gathered from intensity data. For the present time, the seismicity of Albania is characterized by lots of small

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earthquakes and few moderate earthquakes. The earthquake foci are concentrated mostly along the active faults and low velocity layer. The typology of the earthquakes in Albania this year comprises two well-known types of earthquakes: earthquakes with main-shock followed by aftershocks, earthquakes with foreshocks and aftershocks. We present here some features of Seismicity that have occurred in the Albania and surrounding area during 2018.

2. Data and Methods

Seismic phases recorded by the Albanian network, integrated with data of INGV (Italy), Thessaloniki (Greece) and Montenegro networks are used to prepare the database for this study [5].

On Albania and its surrounding territory, between 39°00'-43°00' N and 18°30'-21°30'E, 780 earthquakes was located with M_L = 1.0-5.1 (Richter). In the territory inside the Albanian boundary was located 530 earthquakes (Fig. 1). The standard procedure uses the program Hypo invers [6] of the Atlas package, and velocity model [7] for earthquake locations. Some formula for determination of the magnitude according to the time duration and the amplitude of the seismic signal are also used. There is basic approaches to model the aftershock occurrences Gutenberg-Richter law [8]. G-R relation defines the relationship between the frequency of occurrence and magnitude of aftershocks.

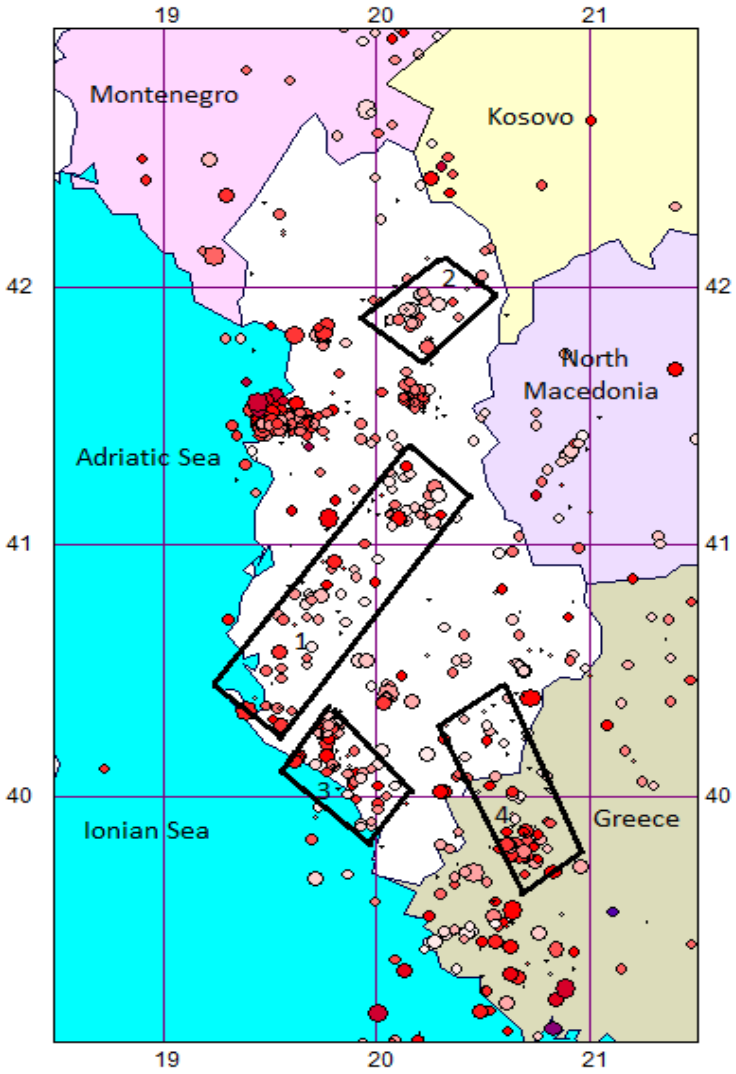

Fig. 1 Epicenters map of earthquakes occurrence during 2018, for the Albanian territory and surrounding area.

3. Results and Discussion

3.1. Some Main Feature of Seismicity

On Albania moderate seismic activity was recorded in some seismogenic zones as: in front of Albanian orogeny, and in transversal fault zones. The most of local earthquakes about 87% are distributed in depth between 0 and 25 km, with average depth 5 km and maximum depth 23 km (Fig. 2). The upper and middle crusts are the seismoactive layers in Albania lithosphere during this year. The mean depth of earthquakes located each month in Albania ranging from 9 to 20 km and maximum depth ranging from 23 to 79 km. The minimum magnitude of earthquakes located each month ranging from 1.0 to 1.5 (Richter) and maximum magnitude ranging from 3.0 to 5.1 Richter. On that territory 39.0-43.0N-18.5-21.5E, 780 earthquakes were located with running magnitude 1.0 to 5.1Richter, 22 of them with magnitude ML >= 4.0 Richter, 5 of them with ML >= 4.5, the strongest with ML = 5.1. About 14 earthquakes were felt by population of Albania. The magnitude of seismic event felt in each month ranging from 3.9 to 5.1 Richter and the number of them for each month ranging from 1 to 7. Maximum number of 191 earthquakes in July is explained with 160 aftershocks of 4 July, Durres earthquake, magnitude 5.2 Rihter. The earthquake foci during 2018 year are concentrated mostly along the active faults. The epicentral distribution of earthquakes shows that: Vlora-Lushnja-Elbasani, Bolen-Borsh-Kardhiq and Kurbnesh-Skavic fault zones (Fig. 1). The seismic activity during this year presented higher compared with seismic activity during period of time 2011-2016 but lower than seismic activity during 2017.

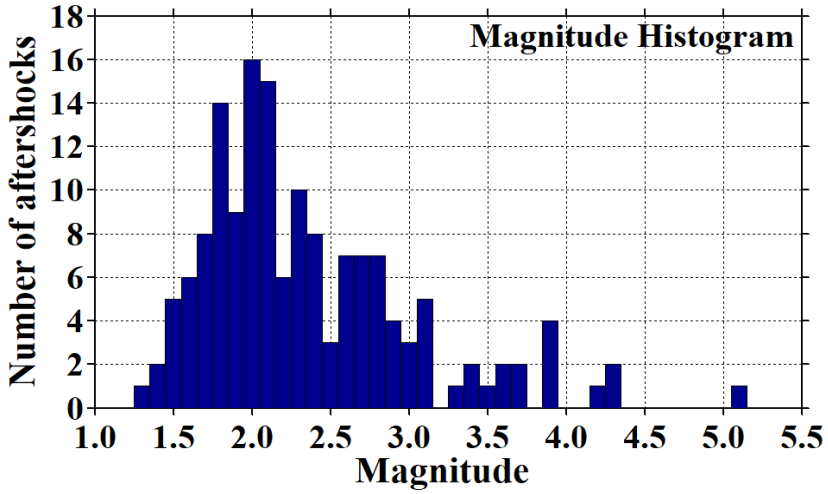

Fig. 2 Magnitude histogram of the aftershock sequence of July 4, 2018 mainshock.

3.2 The Vlora-Lushnja-Elbasani Seismogenic Zone (1)

This transversal fault of northeast strike is expressed by the Lushnja flexure, Dumrea diapire dome, Elbasani Quaternary depression, Labinoti transversal structure, marked by important quaternary infill, Golloborda transversal horst [9] and goes toward Tetova Quaternary graben in FYROM [2, 9]. This fault zone, NE trending for about 100 km in Albanian territory, is consisted of fragmentary normal faults cutting across the Krasta zone and dividing in two main segments the Mirdita ophiolites zone. To this fault zone are related many geological phenomena comprises all four well-known types of earthquakes being seismoactive and now [10]. On this transversal zone were located 72 earthquakes with M_L = 1.0-3.9 (Richter), with average depth 4 km and maximum depth 10 km, and seismotectonic coefficient b = 0.91.

From all earthquakes 10 of them have M_L >= 3.0, and one of them with M_L >= 4.0. The earthquake with magnitude 4.1 (Richter) occurred in Karaburuni pennisula at April 10. Intensity I_0 = V degree EMS-98, felt V degree at Vlora town.

3.3 The Kurbnesh-Skavica Seismogenic Zone (2)

This transversal seismogenic zone with direction SW-NE is in the inner side of folded Alpine orogeny with high mountains (Fig. 1, zone 2). During this year were located 23 earthquakes with M_L = 1.2-3.7 (Richter), average depth 5 km, maximum depth 9 km, and 5 of them with M_L >= 3.0. This fault zone characterized by a complex geomorphology and in addition, has been hit by numerous earthquakes during five last years.

3.4 The Ionian Seismogenic Zone (3)

On the Ionian seismogenic zone a small increase of seismic activity was presented in Vermik-Kudhes segment during 2018 year (Fig. 1, zone 3) On this seismogenic zone were located 108 earthquakes with M_L = 1.2-4.5 Richter, with average depth 11 km, maximum depth 30 km, and 12 of them with M_L >= 3.0, seismotectonic coefficient b = 0.69. The Ionian with west-southeast extension is transverses with left compress and normal component. The left compress evidenced by displacement of the mountain streams [1]. There was a powerful differentiation in the Borsh-Kardhiq fault, closes in the Borsh the structure of Qeparo from the south and at Kardhiqi cuts and seperates the Kurveleshi plateau from the structure of Mali i Gjere through a transversal flysch structure along its, on account of a major tectonic rupture, evaporates, amphibolite and effusive rock crop up from deep and emerge on the surface. Two earthquakes with magnitude 4.5 and 4.2 have occurred respectively: near Vermiku village at 19 May, time 18:14 (UTC) coordinates 40.29N; 19.80E depth 15 km, at 14 May time 10:56 (UTC) coordinates 40.28N; 19.78E depth 17 km. Al series of aftershocks are disturbed in Bolen -Vermik segment part of the Vajze-Bolen-Kudhes-Borsh fractures zone in north-south direction with over thrust/reverse to normal component. On the surfaces of these uplifts, too, there are faults and flexures, expressed also with contrasts in relief; it appears active in this year throughout its length.

3.5 The Ioannina-Leskovik Seismogenic Zone (4)

The study region consists from hilly to mountainous chains striking NW-SE and large basins and grabens that interrupt these chains (Fig. 1, zone 4). This is a seismically active region with a history of strong and moderate earthquakes, such as these of 1969 (Ms = 5.8), 1960 (South Albania, M > 6.5, maximum intensity VIII+) and 1967 (Arta-Ioannina, M = 6.4, maximum intensity IX). Increased seismic activity was registered in Albanian-Greece border in Ioannina-Leskoviku zone. On this fault zone during 2018 year were located 77 earthquakes with M_L = 1.3-4.2 (Richter), average depth 11 km and maximum depth 30 km, seismotectonic coefficient b = 0.78. The Ioannina-Leskoviku segment with direction SE-NW in Albania-Greece board, represent a transversal deep fracture, with springs of thermal water and which was hit by the frequent and strong earthquakes, being active now

3.6 The Serie of Durresi Aftershocks

A strong, M_L = 5.1, earthquake near Durres, Albania, occurred on July 4, 2018 with epicenter coordinates 41.466^{o}N and 19.495^{o}E (Fig. 1). This earthquake occurred at 09:01:07 GMT (11:01:07 a.m. local time) around 18 km underground near the Lalezi Bay, northwest of Durrës and some 30 km west of Tirana. It was followed minutes later by a series of weaker aftershocks, with the strongest measuring magnitude 4.3.

We used 151 aftershocks with local magnitude $M_L \geq$ 1.3 between the time span of July 4, 2018 and September 29, 2018.Most of the earthquakes about 56% of them were in the magnitude 2.0 to 3.0 range. The

sequence activity was developed in the seismically active upper an middle crust beneath Albania, which has a thickness of 25 km [10]. This series of earthquakes were distributed along a E-W belt over the Ionian coastline. Fig. 1 depicts the epicenters of aftershocks. Magnitudes of the aftershocks change between 1.3 and 4.3, and show a decrease in their numbers from the smaller to larger magnitudes.

As shown in Fig. 2, the size of the many aftershocks varies from 1.5 to 4.0 and a maximum is observed for M_L = 2.0. The number of aftershocks with $1.3 \leq M_L < 2.0$ are 61. However, there were 79 aftershocks with $2.1 \leq M_L < 3.5$, and 11 aftershocks with $3.6 \leq M_L$. Thus, the aftershock occurrences having magnitudes between 1.8 and 2.1 are more dominant in the aftershock region (Fig. 2). Cumulative magnitude-frequency of July 4, 2018 aftershock sequence is shown in Fig. 3. We used *Mc* = 1.8 considering the temporal variations. *b*-value and its standard deviation, as well as the *a*-value of G-R relation, were calculated with the maximum likelihood method. *b*-value is estimated as 0.68±0.06 and this value is lower than mean value of *b* = 1.0. For the whole sequences of aftershocks with ML > 1.8, we found cumulative low of distribution:

Log N (M) = 3.36 + 0.68 M +- 0.06

The smaller *b*-values may be related to the low heterogeneity degree of medium, the higher stress concentration and high strain in the aftershock region in recent years [11].

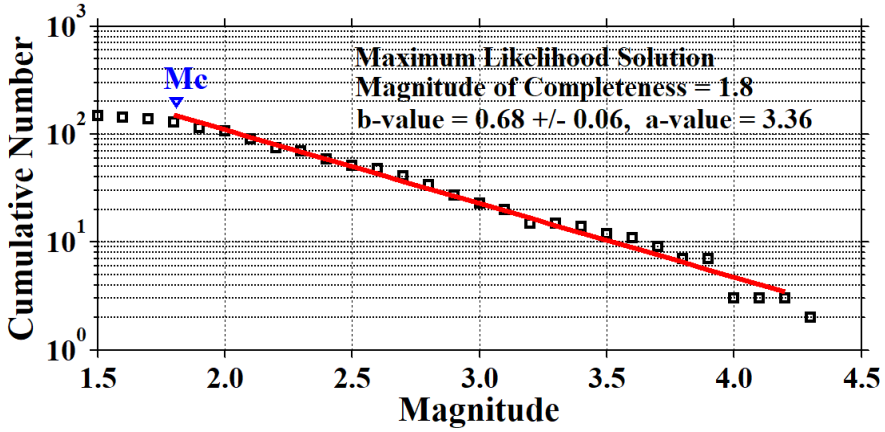

Fig. 3 Gutenberg-Richter relation of aftershock sequence. *b*-value, its standard deviation, *Mc*-value, *a*-value in the Gutenberg-Richter relation.

It is importance to find the ratio between the magnitude of main-shock and the magnitude of the strongest aftershock. For this earthquake, the difference between them is 0.8.

3.7 The Albania-Montenegro Crosses Border Area Earthquakes

Significant increase of seismic activity was registered in north and northwest of Albania in the Montenegro territory. Two moderate earthquakes occurred in the border area of Albania and Montenegro. The first occurred in Plava (M_L4.6) coordinates (42.69N-19.97E) at 4 January 2018 and the second occurred in Ulqini M_L4.6 coordinates 42.15N-19.19E on 13 November 2018. These earthquakes were felt in northern and central of Albania parts.

4. Conclusions

The most seismic activity inside the Albanian territory, analyzed in this paper have been generated in an area with complex features from the nontectonic point of view and structure of earth crust. Moderate seismic activity was recorded in some seismogenic zones as: in front of Albanian orogeny, in transversal fault zones. On the Albania territory and its surrounding, 780 earthquakes were located with running magnitude 1.0 to 5.1 (Richter), 22 of them with magnitude M_L >= 4.0 (Rihter), 5 of them with M_L >=

4.5, and the strongest were Durresi (M_L5.1) earthquake and Bulqiza (M_L5.1) earthquakes. Based on this analysis seismicity in Albania orogeny and its surrounding during 2018 is moderate level, The most of local earthquakes about 87% are distributed in depth between 0 and 25 km, with average depth 15 km and maximum depth 47 km. The analyses of 2018 seismicity show that was mainly generated in the upper and middle crust, under the tectonic conditions described previously. In the vicinity of Durresi was registered the moderate earthquake at July (M_L5.1) and its series of aftershocks. This sequence of aftershocks confirms the NNW continuation of two thrust faulting in north of Durresi area. The small b-value 0.63 of aftershocks series might be related to the low heterogeneity degree of medium, the higher stress concentration and high strain in this region in recent years. In the vicinity of Bulqiza was registered the moderate earthquake at August (M_L5.1) and its series of aftershocks. This sequence of aftershocks confirms the northwest continuation of the normal faulting along this area. Increased seismic activity was registered in the crossborder area of Albania and Montenegro. Compared with last years 2011 to 2017 the seismic activity is the same as seismic activity 2017 year and higher than other years 2011-2016. The strongest earthquakes during this year occurred in central Albania, the seismic activity reached an intensity of VI-VII degrees on EMS-98 scale.

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