Conference Proceedings
CSPM 2020, 16 – 19 September 2021, Virtual edition

Series of Earthquakes from November 2020 to March 2021 between Tetovo-Gostivar and Kichevo Epicentral Area

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Abstract
Manifested Seismic activity was analyzed through a sequence of weak to moderate earthquakes that occurred from November 2020 to March 2021 in the Tetovo-Gostivar region. More than 100 earthquakes were recorded during this period by the telemetric seismological network of the Republic of North Macedonia and neighboring countries. The two strongest earthquakes occurred on November 11th, 2020, at 03h 54min (UTC) and 14h 25min (UTC). As defined by the Seismological Observatory at PMF-UKIM, the local Richter magnitude of these earthquakes was M_L=5.0 and an epicentral intensity I_o=V-VI EMS-1998. The epicenters of these earthquakes were nearby Mavrovo Lake, on the border area between Tetovo-Gostivar and Kicevo epicentral area. Fault-plane solutions of the two strongest earthquakes showed activity of the north parts of the Zajas and Oslomej faults (normal left lateral faulting). The distribution of epicenters is between the north part of the Zajas fault and Mavrovo Lake in the southeastern part of the region. The analysis of the latest events is useful in proving correlation with the past seismic activity as deducted from the historical records.

Keywords: epicentral area, earthquake, source mechanism

1. Introduction

The territory of Southeast Europe where Republic of North Macedonia belongs is one of the seismically most active regions in the continent and therefore the territory is characterized by the highest seismic hazard and risk in Europe.

The territory of Republic of North Macedonia is a part of the Mediterranean seismic belt, as an intra-plate area of active tectonics and high seismicity. This territory represents a complex geological, tectonic and seismotectonic environments where definition and characterization of the seismic zones with a high reliability is quite complex.

Tetovo-Gostivar and Kicevo epicentral area is located in the northwest part of the Republic of North Macedonia. The seismicity of this region is characterized by frequent seismic micro activity$1.0<M_L<3.0$, by a lot of earthquakes with magnitudes $3.0\leq M_L\leq 5.0$ and very rare earthquakes with magnitude $5.0<M_L\leq 5.9$. During the period from November 2020 to March 2021 more than 143 earthquakes were recorded by the telemetric seismological network of the Republic of North Macedonia and neighboring countries.

2. Geology and tectonics

The territory of the Republic of North Macedonia is situated in the central part of southeast Europe, which is in a collision zone between three major plates: Eurasian, African, and Arabian.

The active tectonic processes in the eastern Mediterranean are most influenced by the subduction of the Adriatic microplate under the Dinarides; subduction of the Ionian and Levant microplates under

the Hellenic trench; and the collision between the Eurasian and the Arabian plates, related to the North Anatolian Fault zone (Burchfiel et al. 2006).

Because of these regional processes, the seismicity of the territory of North Macedonia is associated with recent tectonic movements along normal faults (e.g., Dumurdjanov et al. 2004). These faults are related to the extension and neotectonic vertical differential motions.

The region between Tetovo-Gostivar and Kicevo epicentral area is geologically and seismotectonically rather complicated, located on the border of North Macedonia, Kosovo and Albania, between the first order tectonic structures, namely the West-Macedonian Massif on West, the second order Massif of Pelagonia on East and second order Vardar zone on the northeast (Jordanovski et al. 1998).

The neotectonic activity in this region is a result of the permanent uplifting of the terrain, by differential vertical movements from Shara, Bistra and Pesjak Mountain, and sinking of Polog and Kicevo valleys (Arsovski, Petkovski, 1975).

An active trending graben structure in this region is NE-SW in upper part and NW-SE in lower part, with normal faults that have a clear expression as fault scarps in the present-day landscape: northern part - Shara, Zeden, Suva Gora and Mavrovo Faults; southeast part – Zajas, Oslomej and Pesjak Faults. The latest faults are placed at the east margins of the Kicevo valley with very weak seismic activity, Fig.1 (Arsovski, 1996).

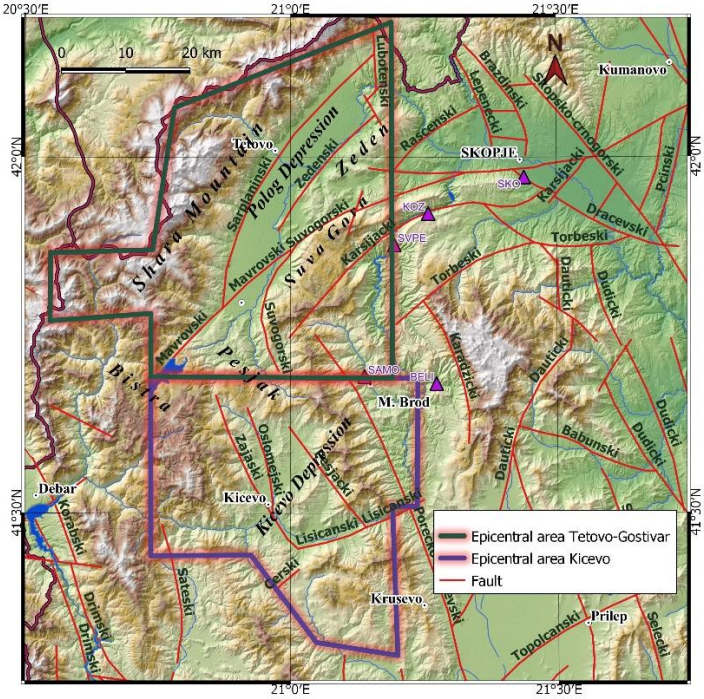

Figure 1: Tectonic map of the region

3. Seismic activity in epicentral areas Tetovo-Gostivar and Kicevo from November 2020 to March 2021

Instrumental seismological and macroseismic data, available at the Seismological Observatory of the Faculty of Natural Sciences and Mathematics in Skopje, were used for studding the seismicity of the Tetovo-Gostivar and Kicevo area.

The weak earthquakes are very frequent, the light to moderate earthquakes are relatively rare, while the strong earthquakes are rare. The predominant hypocentral depth is in the interval 0-20 km. The seismicity is due to the activity of all approximately NE-SW and NW-SE oriented faults. Namely, all the faults are tectonically active.

The Tetovo-Gostivar and Kicevo epicentral area exhibited high seismic activity expressed through a sequence of slight to moderate earthquakes from November 2020 to March 2021, [4]. Epicentral map

shows 143 located earthquakes with magnitude $M_L \geq 0.1$, according to the Seismological Observatory of the Faculty of Natural Sciences and Mathematics in Skopje, Fig.2. Most of the earthquakes were felt. Parameters of the strongest earthquakes are given in Table1.

Table 1: The strongest earthquakes in Tetovo-Gostivar and Kicevo epicaentral area with $M_L \geq 4.0$; φ and λ latitude and longitude of the epicentre; *h*-hypocentral depth; *Io*- maximal observed intencity

Year	Month	Day	h:min:s	φ	λ	h(km)	M_L	*Io*
2020	11	11	03:54:14.73	41.61	20.85	15.0	5.0	V-VI
2020	11	11	14:25:12.97	41.59	20.87	11.8	5.0	V-VI
2021	3	12	21:17:07.75	41.66	20.74	17.2	4.6	V
2021	3	12	21:28:40.64	41.63	20.73	15.0	4.4	IV-V

Focal mechanism solution was found for four of them with magnitude $M_L \geq 4.0$, Fig.3. The epicenters distribution of the studied period is spread throughout a wide area crisscrossed by fault ruptures and shows activation of variously oriented raptures of numerous dimension levels.

The epicenters of the strong earthquakes were located between the Zajas and Oslomej faults.

The fault plane and the direction of the corresponding slip, which together define a normal left-lateral faulting and NNE striking fault, as possible earthquake source, were found by comparison of the P nodal solution obtained from the first *P* onsets polarities.

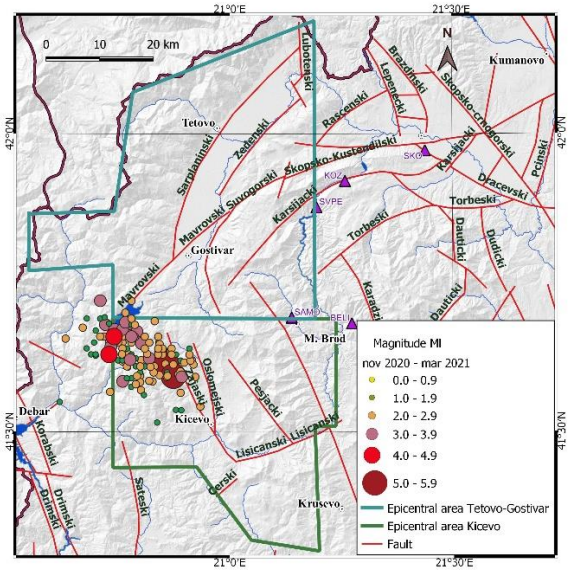

Figure 2: Epicentral map of the earthquakes from the sequence November 2020-March 2021 in the Tetovo-Gostivar and Kicevo region.

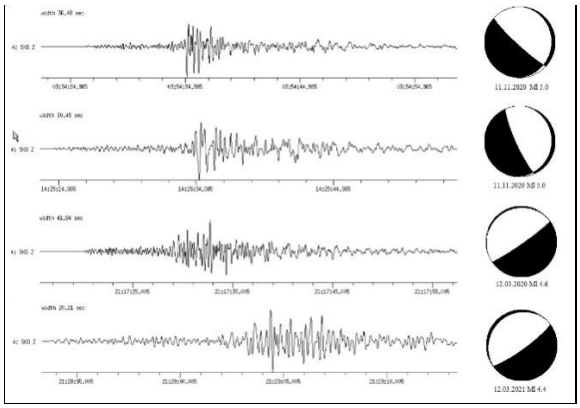

Figure 3: The waveforms of the vertical components of the strongest earthquakes recorded at the station in Skopje (SKO) and the corresponding P-nodal solutions (beach balls).

Hypocenter depths scatter between 7km and 20 km. Small and moderate earthquakes ($M_L \leq 4.0$) take place predominantly along major fault zones and are concentrated along the margins of Mavrovo Fault and northern part of the Zajas and Oslomej Fault, Fig 4.

According to the results of statistical methods in the survey of the observed seismic activity in the Tetovo-Gostivar and Kicevo region, the maximum possible earthquake intensity expected for 100 years is the VII-VIII degrees EMS-1998, Fig 5.

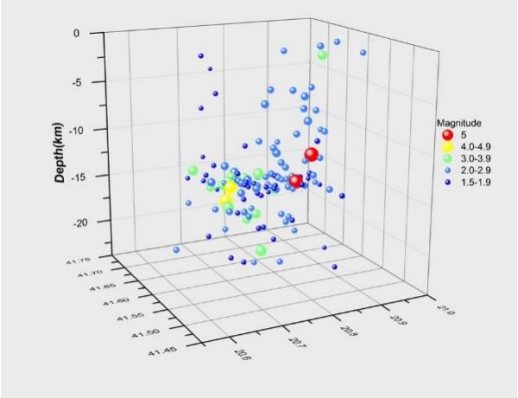

Figure 4: 3D distribution of the earthquakes from the sequence November 2020 to March 2021 in Tetovo-Gostivar and Kicevo region.

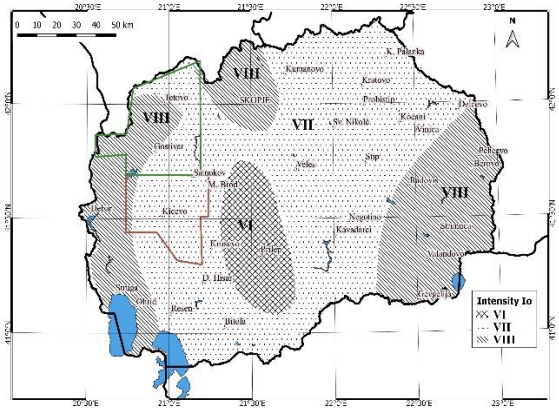

Figure 5: Maximal expected intensity for the return period of 100 years.

4. Conclusions

For the five months period, November 2020 – March 2021, the Tetovo-Gostivar and Kicevo epicentral area experienced a series of slight to moderate earthquakes. More than 140 earthquakes were recorded, and 20 of them were with magnitude $M_L \geq 3.0$. The two strongest earthquakes, that occurred on November 11th 2020, had magnitude $M_L=5.0$ and maximum intensity I_o=V-VI degrees on the EMS-1998 scale. Epicenters belong to Mavrovo fault and north part of Zajas and Oslomej Faults. The earthquakes that occurred were with depths of about 15 km (upper, granite layer of the earth's crust).

In accordance with the latest survey of the seismic parameters and the seismic hazard assessment for the territory of North Macedonia, it can be expected that Tetovo-Gostivar and Kicevo epicentral area will be exposed to macroseismic effect of VII-VIII degrees according to EMS-98 for a return period of 100 years. The results are expected to be important in hazard and risk assessment for the Balkan Peninsula.

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