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SEISMIC ACTIVITY WITHIN OGRAZHDEN MOUNTAIN FOR THE PERIOD OF TIME 1978-2016

Abstract: Ograzhden (Ograzhdenets peak - 1748 m) is a small border mountain between the Republic of Bulgaria and the Republic of Northern Macedonia. It is part of the Osogovo-Belasitsa mountain group. Its geographic position within the eastern part of the Balkan Peninsula suggests proximity to the main tectonic processes in the Eastern Mediterranean region. This reflects the geodynamic processes in the region and, in particular, the seismic picture. The present study focuses on seismic activity within Ograzhden Mountain for the period of time 1978-2016. For this purpose, a free seismic catalog of 145 earthquakes (all values) from IRIS (Incorporated Research Institutions for Seismology) was used. Overall, the results show that seismic activity within Ograzhden Mountain is moderate, dominated by weak and shallow earthquakes. Seismic epicenters are situated mainly on the southeastern parts of the mountain and mark the boundaries between individual mobile Earth's crust blocks.

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INTRODUCTION

Geographically, Ograzhden Mountain is located within the eastern part of the Balkan Peninsula (Fig.1). Ograzhden Mountain is bordered to the north by Maleshevo Mountain through the Lebnitsa River Valley. To the south and southwest the valley of the Turiya River (a left tributary of the Strumeshnitsa River) separates it from Dragolevo Mountain. The valley of the Struma River serves as eastern border. Ograzhden Mountain stretches from west to east to a length of about 50 km. Its width reaches 17 km. From the south to the north crosses the state border between the Republic of Bulgaria and the Republic of Northern Macedonia, where is located its highest point- the Ograzhdanets peak (1748 m). In the Bulgarian part, the highest point is Bilska chuka peak (1644 m), which is an important hydrographic knot. Other more well-known peaks are Markovi kladentsi peak (1523 m), Muratov peak (1398 m), Kukovski chukar peak (1233 m), etc. (*Nikolov* et al., 2013).

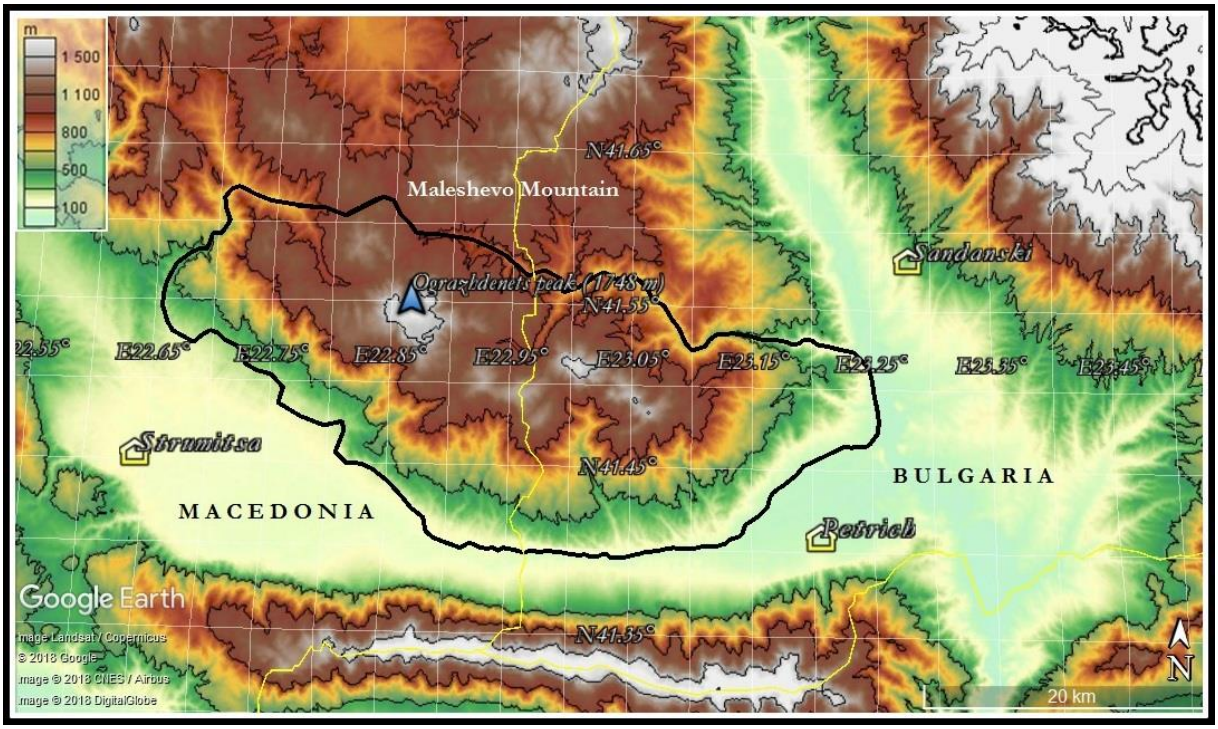

Figure 1 Geographic position of the Ograzhden Mountain within the eastern part of the Balkan Peninsula

In tectonic sense the surveyed territory is subject to ongoing intercontinental collision between European southern margin of the Eurasian (Neo Europe) and northern margin of the African (Gondwana) tectonic plates (Fig.2) (*Dewey* et al., 1989; *Le Pichon* et al., 1988; *Royden* and *Burchfiel*, 1989; *Argnani*, 2006; *Tzankov* et al., 2015, 2016, 2017, 2018). In the region of the Aegean Sea the tectonic situation is further complicated by the movement of Arabian plate to the northwest (*Dewey & Sengör*, 1979; *Sengör* et al., 1985, 2005; *Hubert-Ferrari* et al., 2002; 2009). This process activates the North Anatolian transform fault and further increases seismicity in the region. A significant part of created in these processes seismic energy is "released" in the areas of the Struma River Valley and the Strumeshnitsa River Valley, which surrounds Ograzhden Mountain to the southeast and south. This explains the increased "secondary" seismic activity in this part of Southwest Bulgaria (*Tzankov* et al., 2016, 2017).

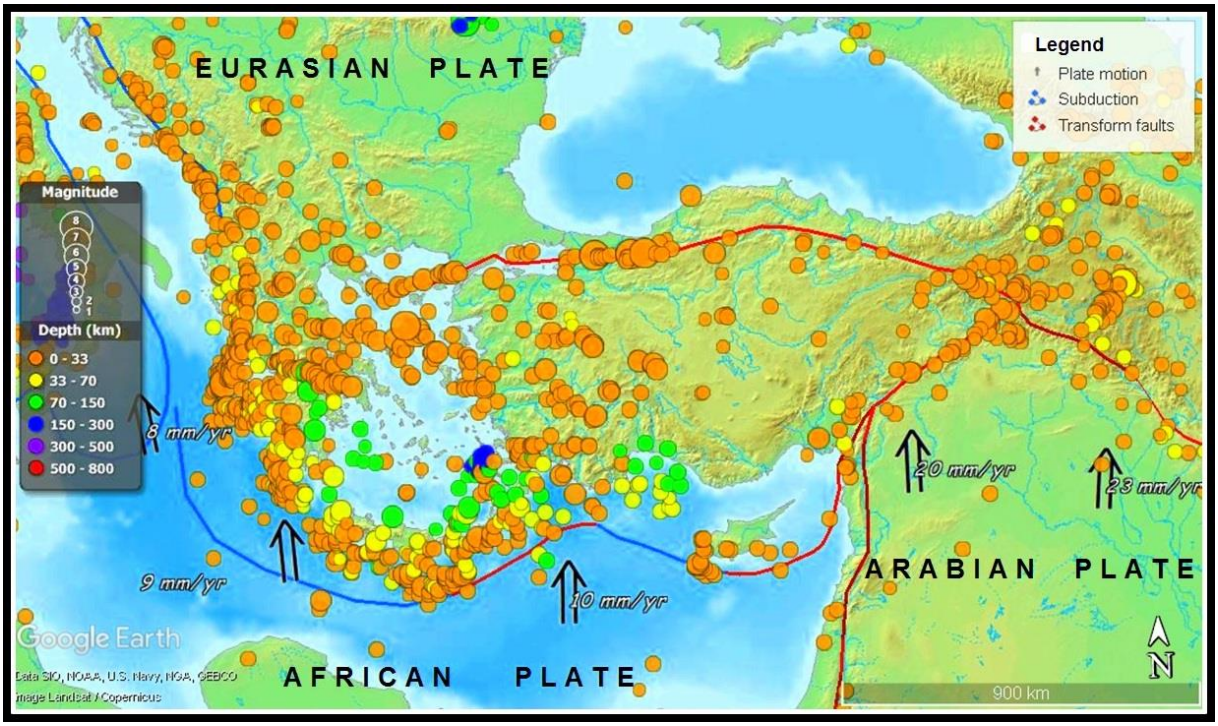

Figure 2 Main tectonic processes in the Eastern Mediterranean region (GIS data: USGS)

Given that Ograzhden Mountain is sufficiently close to the main tectonic processes in the Aegean region. This inevitably affects the nature of seismic activity. In seismic terms the Ograzhden Mountain area is part of the Struma seismic region (within the Aegean seismic zone of the Alpine-Himalayan seismic belt). The Struma seismic region is one of the most dangerous parts within continental Europe. Seismicity here is a specific reflection of the processes in the Earth's crust. All of these influence the seismic hazard within Ograzhden Mountain. Earthquakes here have expected intensity to IXth degree of MSK-64 scale (*Bonchev* et al., 1982) and expected magnitude to 5.1-5.5 on the Richter scale (*Christoskov* et al., 2006; *Botev* et al., 2013). This predetermines the high seismic hazard and requires a geodynamic interpretation of the tectonic processes creating and controlling seismic activity in the area.

The main goal of the proposed study is to present the results of the seismic activity analysis within Ograzhden Mountain (for the statistical of period 1978-2016) based on the contemporary Plate tectonics model for this part of the world. For this purpose several graphs and earthquake distribution map of the study area were created.

METHODOLOGY AND DATA

The proposed study is based on the contemporary Plate tectonics concept for the eastern part of the Balkan Peninsula. The theoretical foundations of these ideas are set out in several previous publications (*Tzankov* et al., 2015, 2016, 2017, 2018). In the course of the seismic analysis within Ograzhden Mountain, a free earthquake catalog from the IRIS (Incorporated Research Institutions for Seismology) (online available from https://www.iris.edu/hq/) was used. The catalog includes 145 earthquakes (all values) for the statistical of period 1978-2016. Some map layers from USGS Seismic Hazard Program (online available from https://earthquake.usgs.gov) also was used. The GIS data visualization was performed using the free software GoogleEarthPro.

SEISMIC PROFILE WITHIN OGRAZHDEN MOUNTAIN FOR THE 1978-2016 STATISTICAL OF PERIOD

In spatial terms, the earthquake epicenters within Ograzhden Mountain territory are located mainly on the southeastern edge of the mountain. Within the studied period 1978-2016, the western parts of the mountain are almost non seismic (Fig.3).

The low magnitude earthquakes dominate the territory of Ograzhden Mountain (Fig.3, Fig.4). The strongest seismic phenomenon for the studied period has a magnitude of 5.1 on the Richter scale. It was occur in 1985 along the dome-like morphostructure along the southern margin of the mountain.

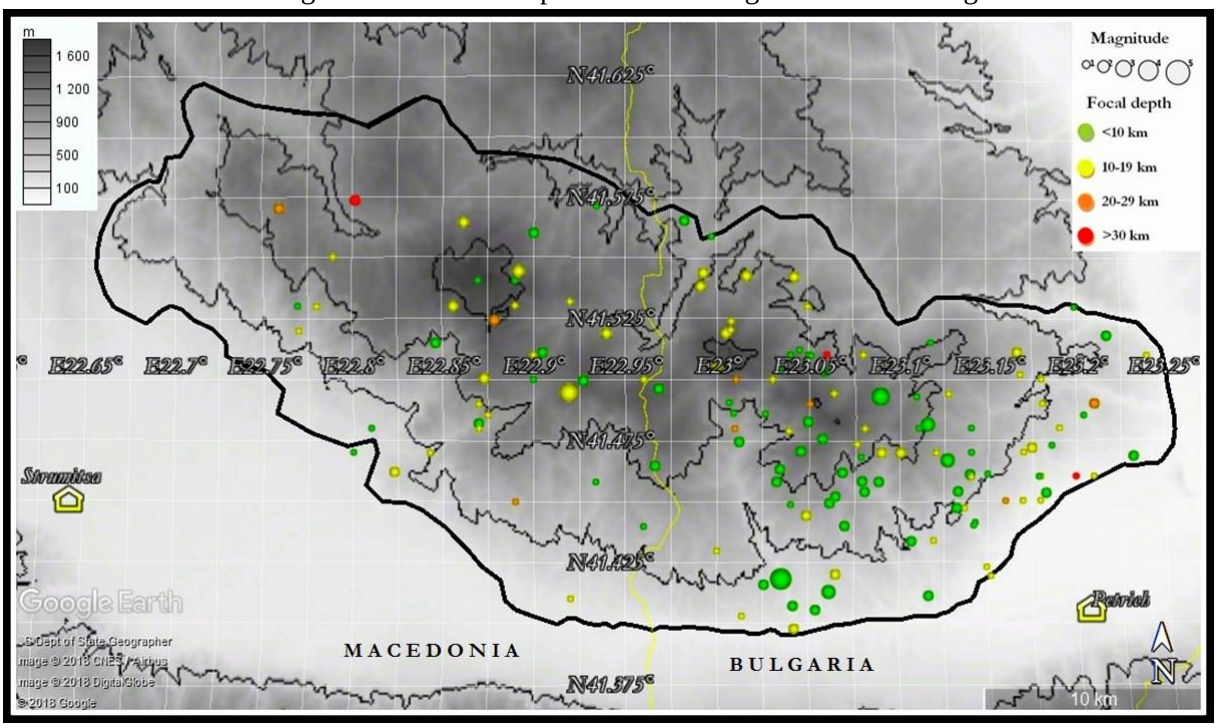

Figure 3 Spatial spread of earthquakes within Ograzhden Mountain for the period 1978-2016

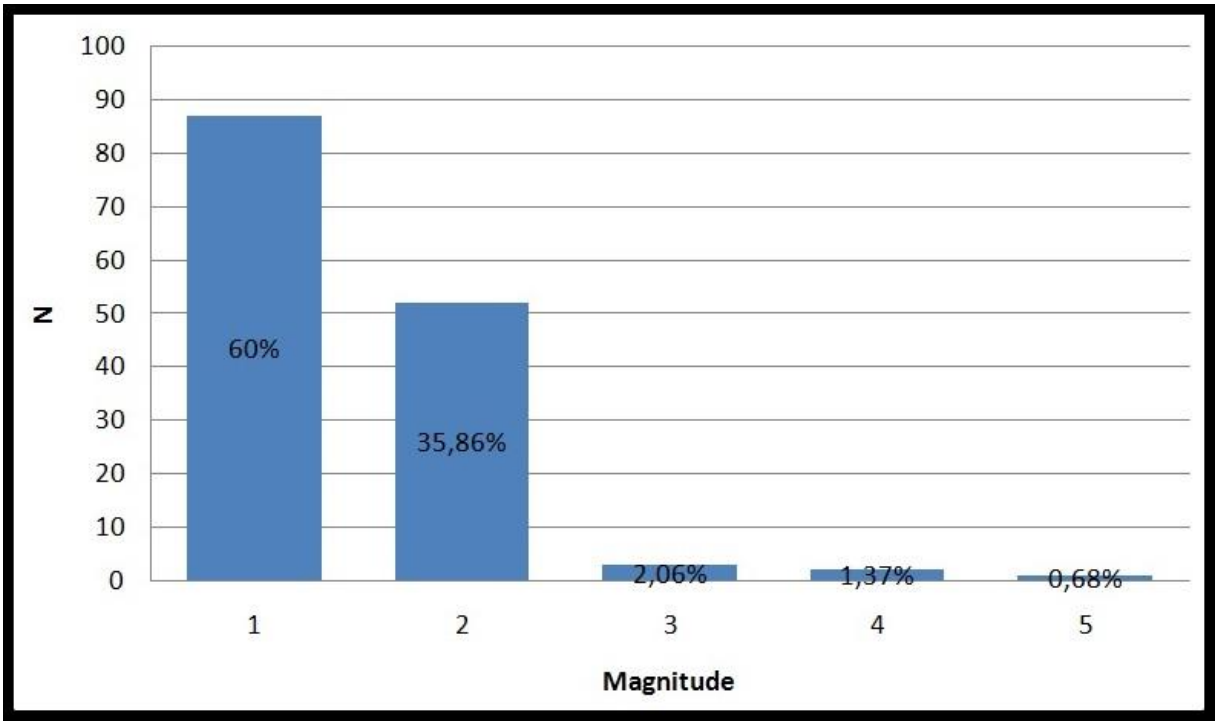

Figure 4 Distribution of earthquakes in Ograzhden Mountain by magnitude for the period 1978-2016

In general, the small energy of the earthquakes is combined with a small focal depth (Fig.3, Fig.5, Fig.6). For the research period, the deepest seismic events reach 31-33 km. But these are single cases and it is inconspicuous earthquakes. Near surface seismic events dominate.

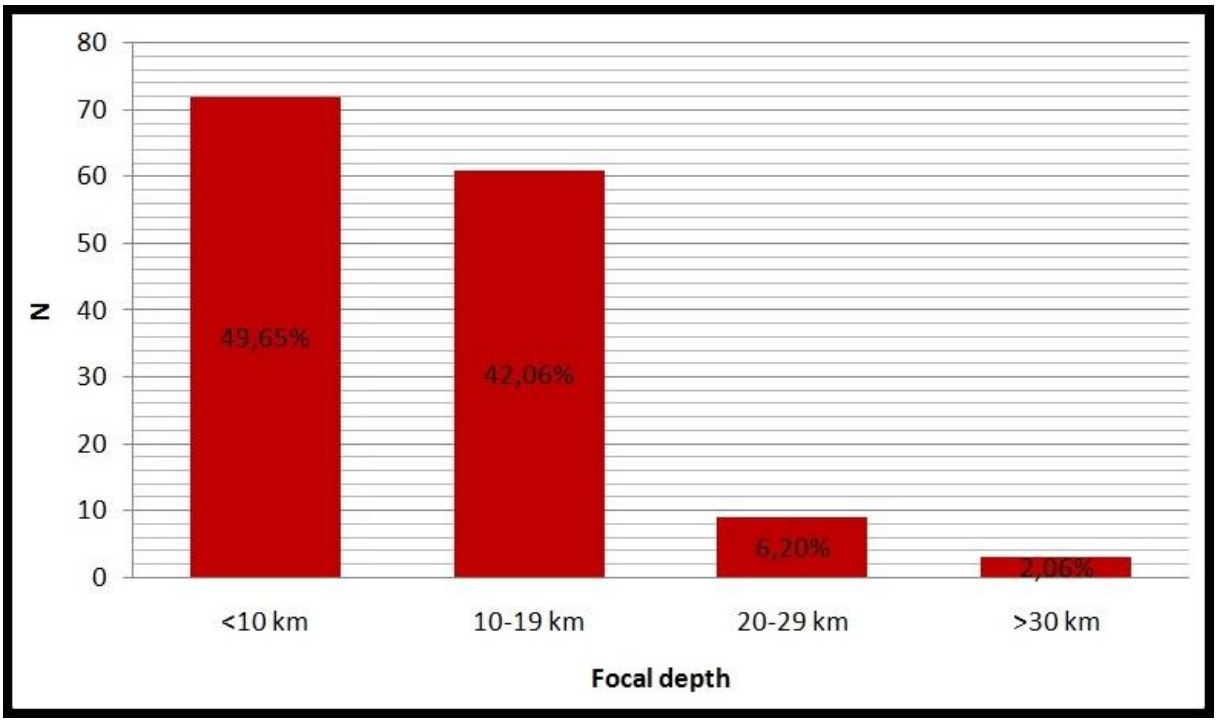

Figure 5 Distribution of earthquakes within Ograzhden Mountain by focal depth for the period 1978-2016

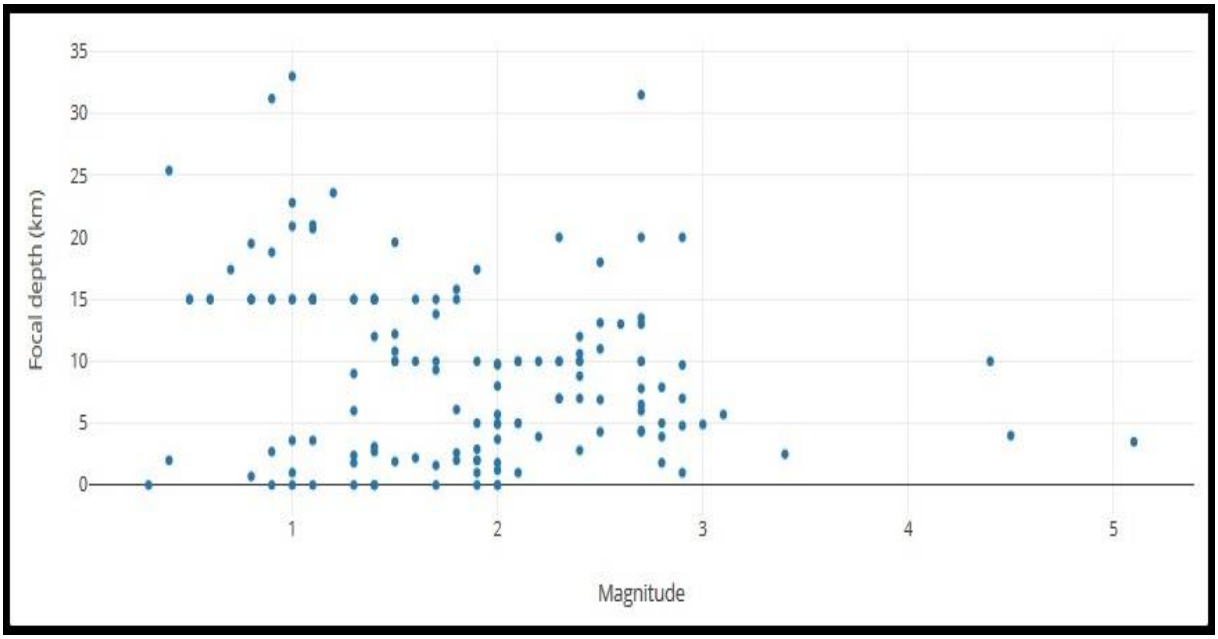

Figure 6 Magnitude/focal depth correlation of earthquakes within Ograzhden Mountain for the period 1978-2016

Over the last decade (2006-2016) there has been a marked increase in seismic activity within the Ograzhden Mountain (Fig.7). Compared to the previous decade (1995-2005), there is also a slight increase in the power of individual seismic events.

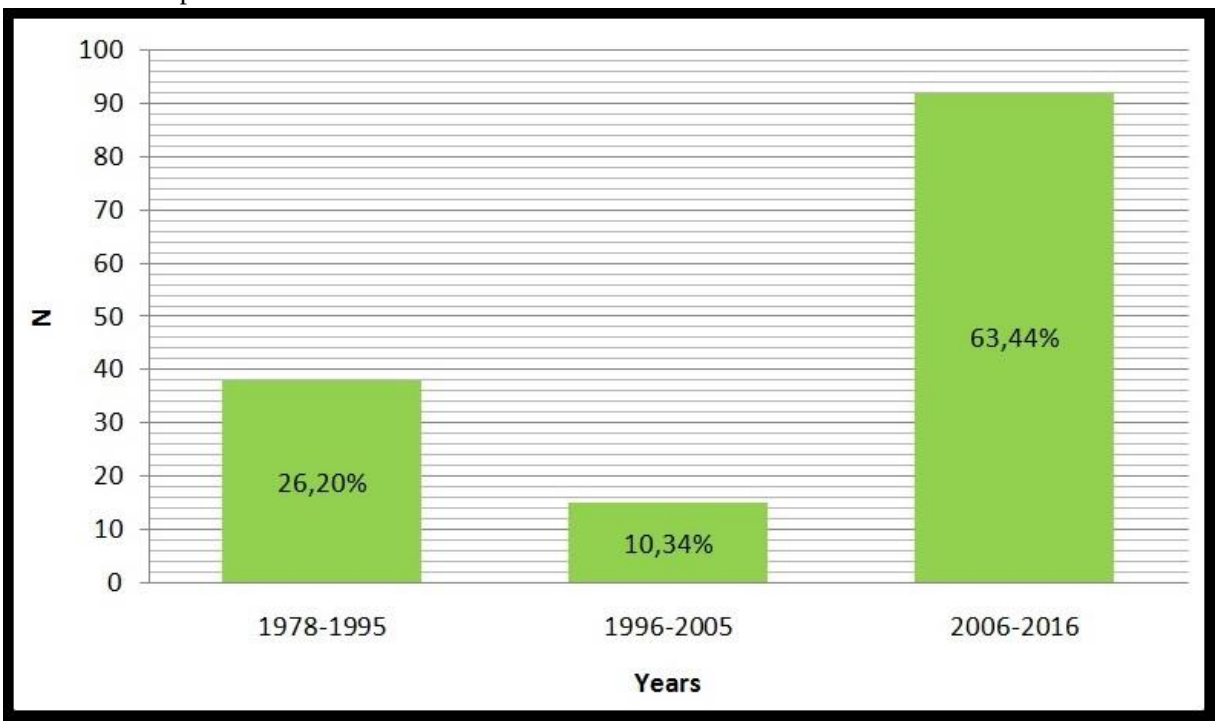

Figure 7 Distribution of earthquakes within Ograzhden Mountain by years for the period 1978-2016

RESULTS AND DISCUSSION

The results obtained in the course of the study can generally be summarized as follows:

1) The seismic phenomena within Ograzhden Mountain are concentrated mainly along eastern parts of the mountain and mark the edges of the local dome-like morphostructures. The western part of the mountain is almost seismically no active.
2) For the study period (1978-2016) almost 96% of earthquakes are very weak (M≤3). The stronger earthquakes (M≥4) consists only 2% of total number of events. The strongest earthquake is 5.1 on the Richter scale (1985).
3) The earthquakes within Ograzhden Mountain have a maximum focal depth to 31-33 km, dominated by the depths less than 20 km (91.7% of all cases). This is an attestation of the totally near surface nature of seismic processes.
4) Over the last decade (2006-2016) there has been an increase in seismic activity within Ograzhden Mountain. Moreover, for the period 1978-2016, 63.44% of all earthquakes occurred in the last 10 years.

In general, Ograzhden Mountain is characterized by higher seismic hazard compared to the neighboring mountains. Increased seismic hazard within Ograzhden Mountain is not associated with high seismic risk. The mountain itself is extremely sparse populated. In the immediate vicinity there are no big towns, and apart from several larger villages, the settlements are small with a constantly decreasing population. Therefore, the seismic activity of Ograzhden Mountain is a minor threat to the infrastructure in the region.

CONCLUSION

The conducted study reflects the results in relation to the seismic activity analysis within Ograzhden Mountain. In general, Ograzhden Mountain is characterized by moderate seismic activity. Seismic phenomena are mostly weak and occur at a small depth. This is conditioned by the nature of the tectonic processes that create them. In general, Ograzhden Mountain is characterized by a higher seismic activity than the neighboring mountain morphounits. This is explained by the fact that Ograzhden is the "edge" of the monolithic body of the Osogovo-Belasitsa Mountain Range (excluding the geographically separated Belasitsa Mountain). The climbing of seismic epicenters in the central and eastern parts of Ograzhden Mountain is related to the proximity to the main active fault structures along the valleys of the Struma and Strumeshnitsa rivers. These are the main "vent" for accumulated tectonic stresses in this part of the Balkan Peninsula. Increased seismic activity in the central and eastern part of the mountain leads to significant internal block breakage. Given the foregoing, there is every reason to believe that the current seismic situation within Ograzhden Mountain will continue in the future.

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