Seismicity at and Around Macedonian-Bulgarian Border

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Abstract: The present paper provides a review of the seismicity of the region at and around the Macedonian-Bulgarian border situated between 22^0-24^0 east longitude and 40.5^0-42.5^0 north latitude. Investigations that have so far been performed and published by Macedonian and Bulgarian researchers as well as joint teams involved in different scientific and applicative projects have been used.
The analysis presented here were performed aimed at definition of the seismic risk for the lifeline systems (oil and gas pipelines, roads, road -Corridor 8 etc) passing through both neighboring countries. The support within the framework NATO-ESP.EXP.CLG.983911 project is acknowledged.

Key words: seismology, geology, seismic focus, seismic intensity, magnitude

1. INTRODUCTION

R. Macedonia and Bulgaria spatially belong to the Balkan region, which is characterized with high seismic hazard. The losses due to occurred earthquakes amount of 20–30 millions of euros on an annual basis. Therefore, the development of a strategy for seismic protection is one of the important long term goals of all the countries in the Balkan region.

Due to the high seismic activity of the Balkan region and the spatial distribution of the states, the seismic protection of each individual country in this region does not only depend on the effect of the seismic foci within the existing boundaries but also the effect of the seismic foci in the neighboring countries as well as those on the very common borders between the countries. The existence of political borders imposes performance of joint investigations related to the seismicity of the area around the common border. This is of a great importance particularly for seismic design of structures and infrastructure, i.e., the trans-regional lifeline systems that regionally connect the neighboring countries and require joint investments like oil pipe lines [Talaganov et al. 1999, 2003], gas pipe lines [Milotinovich, et al. 1996, Milotinovich and Trendafilovski 1996], roads, railway lines (Corridor 8) and other lifeline systems.
The seismic characteristics presented herein will be used as the basis for mathematical modeling of seismicity and definition of recurrence relationships for the analyses of the seismic hazard and risk of the considered region.

2. SEISMIC CHARACTERISTICS

The seismic activity is associated with the tectonic deformations that in the Neogene Quaternary were characterized by particular mobility conditioning manifestation of destructive processes as intensive recent faulting and reactivation of older pre-neotectonic ruptures. Numerous geological, geomorphological and geodetic data as well as the frequent occurrence of earthquakes confirm that the trend of these processes, with negligible deviations, continues also in the recent development. Therefore the tectonic, neotectonic and seismotectonic characteristics of the region are of a particular importance for seismic risk assessments.

2.1 Tectonic, Neotectonic and Seismotectonic Characteristics

In the considered region as part of the Balkan region, there are several micro-plates that represent parts of the Alpine orogene system given in Figure 1 (Arsovski M., 1997). The scheme with the main tectonic units according to Petrovski et al., 1992 is shown in Figure 2.
In the neotectonic phase, the considered region was exposed to intensive tectonic motions manifested by significant block modeling. So the Stara Planina mountainous massif was affected by uplifting, while in the Srednogorje zone, mountainous massifs and longitudinal depressions were formed.

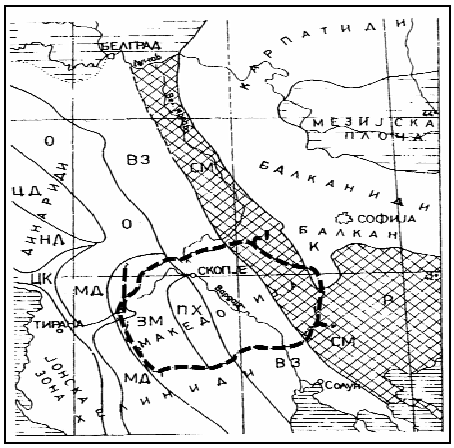


Figure 1. Central part of the Balkan region (**SM**-Serbian Macedonian massif, **R**-Rhodopes, **VZ**-Vardar zone, **K**-Kraishtides (Arsovski M., 1997).

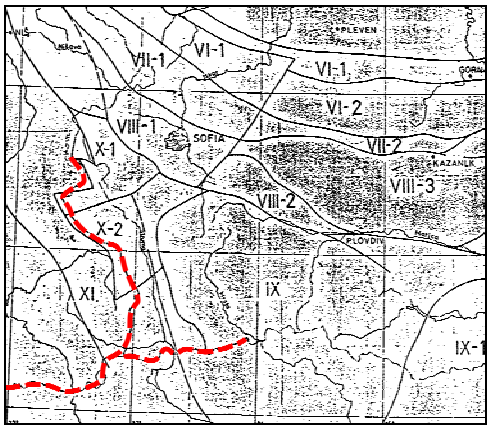


Figure 2. **Scheme of tectonic units** (**XII**-Vardar zone, **XI**-Serbo-Macedonian massif, **X**-Kraishtides, **IX**-Rhodopes, **VIII**- Srednogorie, **VI-VII**-Balkan (Petrovski et al., 1992).

The Maritsa fault as a neotectonic dislocation along the south edge of Srednogorje is also active today and is known as the Plovdiv dislocation. The Rhodopian massif is affected by most intensive vertical uplifting motions (Rila mountain) and subsidence (the depression along Mesta and Struma rivers). The marginal faults of the depressions are still active today. The Serbian-Macedonian massif is affected by uplifting of differential character whereby longitudinal and transverse depressions (Kochani depression) have been formed. The Kraishtide zone was uplifted up to 1200 meters in the Neogene's, with longitudinal depressions (Kustendil), while presently it is affected by uplifting of 1-2 mm/per annum. The neotectonic formations as special morph structural units are separated from each other by faults as carriers of seismic activity. The neotectonic map of the target region is presented in Figure 3 (Petrovski et al., 1992). The isolines show the amplitude of terrace's uplift or subside.

The seismotectonic map defined by the correlation between seismological and tectonic data (Figure 4, Petrovski et al., 1992) shows that a number of focal zones are situated in the considered region among which Kresna and Valandovo are zones exerting the strongest seismic effect.

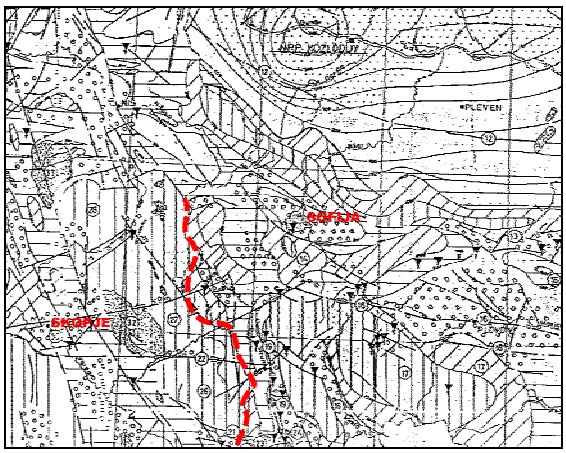


Figure 3. **Neotectonic map of the target region.** *(After: Arsovski M., Matova M.,)* (Petrovski et al., 1992).

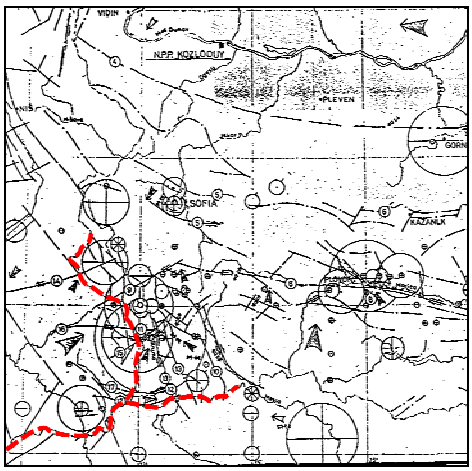


Figure 4. **Seismotectonic map of the targe region.**(*Structural elements after:* Arsovski M., Matova M. *Seismological elements after*: Sokerova D., Glavcheva R., Simeonova S., Botev E., Dineva S., Solakov D., Dinkova K., Babachova S., Nikolova S., Maslinkova S., Radu C., Hadzievski D.), (Petrovski et al., 1992).

Recent motions defined by earthquake monitoring in SW Bulgaria by space geodesy and the National Seismological Network point to vertical motions of different values, whereas the seismic activity in the period from 1990 to 2002 is characterized by slight earthquakes (Dimitrov D.S., et al.., 2001).

2.2 Observed Seismicity

The easiest way to follow the seismic history is through data on occurred earthquakes contained in the catalogues on occurred earthquakes and through investigation of the macroseismic effects given in degrees according to the macroseismic scales. Depending on the time of their occurrence, the earthquakes, for example in R. Macedonia, are divided into three time categories (Jordanovski Lj. et al., 1998) as follows: data from the period prior to 1900, the period 1901 – 1963 and the period after 1964). The time period prior to 1900 was used in the investigations done in Bulgaria (Ranguelov, B., et al., 2010) and for these investigations it is characteristic that the data on the occurred earthquakes are only macroseismic based on historic, church's, chronical, archaeological, memoaric records. In the second time category, i.e., after 1900, the main data are macroseismic but there are also instrumental data obtained by a great number of seismographs in regional and international seismological centers.

2.2.1. Kresna Seismic Focus

The strongest earthquake in Kresna seismic source occurred on April 4, 1904. Its magnitude is estimated at 7.8-8.0 (Christoskov and Grigorova 1968, Ambraseys 2001) and this value is accepted in the world earthquake catalogues (Shebalin et al., 1974). It is well known as Kroupnik earthquake. Other strong earthquakes with M=7.2 occurred just 23 minutes before the one mentioned above. The location of the epicentral zone of both earthquakes has not been clarified yet. Macroseismic data show that the most significant damages and loss of lives were located in the area Kroupnik-Pehchevo-Kochani. The macroseismic map of the 04.04.1904 earthquake shows that the impact of this earthquake (or earthquakes) on the area was of intensity between X and VIII (Figure 5, Shebalin at al., 1974; Ranguelov B. et al., 2001).

2.2.2. Valandovo Seismic Focus

The Valandovo seismic focus is characterized by high recent tectonic destruction of the Earth's crust where faults of Vardar direction intersect (old faults that are now reactivated) with faults of transverse and diagonal character. In the Valandovo area, in a complex tectonic knot, a catastrophic earthquake with magnitude M_L=6.7 and intensity I=X MM, depth h=10 km. (Figure 6) took place in 1931. In this area, slighter earthquakes are also manifested. These are associated with the activity of individual local faults of gravity character (Talaganov et al.., 1999).

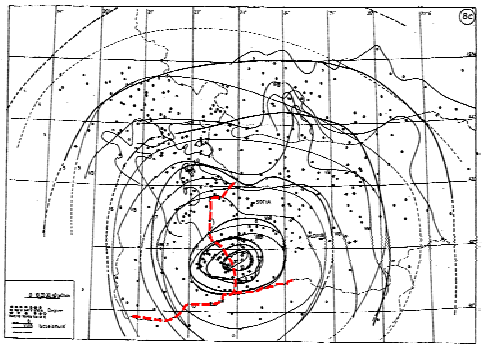


Figure 5. Macroseismic map for the catastrophic Kresna earthquake of April, 4, 1904 (Shebalin at al., 1974).

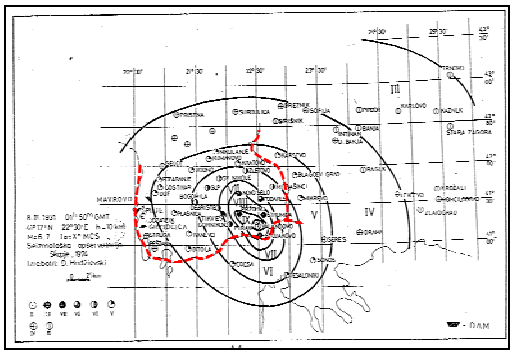


Figure 6. Macroseismic map for the Valandovo earthquake of March 8, 1931 (Talaganov et al., 1999).

2.3 Prognosticated Seismicity

The prognostication of the size of the seismic intensity has a particular importance in the elaboration of seismic design codes. It is defined by elaboration of hazard maps for different parameters of ground motion under the effect of strong earthquakes. For their computation, catalogues of historic and instrumental data, macroseismic data represented by isoseismals of seismic intensity, data on geology, netoectonic and seismotectonics are used.

The hazard maps per seismic intensity computed for different time periods are the basis for the codes on seismic design in both countries. According to the hazard maps, the prognosticated intensity for the Kresna and Valandovo foci is 9 and 8 degrees according to the MSK-64 scale for return periods of 500 and 100 years, respectively (Official Gazette of SFRY no. 31 dated 5th June 1981). More recent hazard maps for the territory of R. Bulgaria were published in 2006 (Simeonova S. et al., 2006) and 2008 (Leidecker G. et al., 2008). According to these maps, the Kresna focus is expected to exert an intensity of 8.5-9.5 and 7.5-8.5 degrees according to the MSK-64 scale for return periods of 475 and 95 years. For a return period of 2475 years, the expected seismicity is 9.5-10.5 degrees according to the MSK-64 scale.

Conclusion

The seismic characteristics of the region at and around the Macedonian-Bulgarian border show that it is characterized by very high manifested and prognosticated seismicity wherefore it is necessary to predict the characteristics of ground motion not only through hazard maps per intensity but also hazard maps per maximum accelerations and response spectra.

Acknowledgement

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