SECOND EUROPEAN CONFERENCE ON EARTHQUAKE ENGINEERING AND SEISMOLOGY, ISTANBUL AUG. 25-29, 2014

NEW DEVELOPMENTS IN PROBABILISTIC SEISMIC HAZARD ANALYSIS FOR ROMANIA

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The seismic hazard analysis can be approached in a deterministic or a probabilistic manner. The probabilistic seismic hazard analysis has the advantage of fully integrating all the aleatory uncertainties arising from seismicity and ground motions parameters expected in a future earthquake on a particular site. The epistemic uncertainties are included as well through the use of logic tree approach. In this study new developments in the probabilistic seismic hazard assessment for Romania are presented.

The seismic sources contributing to the earthquake hazard of Romania are defined in the studies of the National Institute for Earth Physics, *INFP*. In Figure 1 (Vacareanu et al., 2014) the seismic sources influencing the Romanian territory are presented: 13 sources of crustal depths and one enclosing the intermediate-depth seismicity manifested in Vrancea region. The contours of the seismic source's areas are refined, keeping the same stress field characteristics, starting from the study of Radulian et al (2000) to take into account the distribution of recent seismicity. The Serbia source is defined taking into account the known fault distribution and the epicentres of events with moment magnitude M_W at least equal to 5 as reported in SHARE catalogue (Stucchi et al., 2013). Sources in North Eastern Bulgaria are defined after (Simeonova et al, 2006).

Out of the 14 seismic sources presented in Figure 1, Vrancea subcrustal seismic source is the most active and powerful and is influencing more than two thirds of the Romanian territory as well as parts of Republic of Moldova and Bulgaria. A detailed description of the seismological features of the Vrancea intermediate-depth seismic source is beyond the scope of this paper and relevant information can be found elsewhere (e.g. Radulian et al., 2000; Ismail-Zadeh et al., 2012; Lungu et al., 2000).

The magnitude of completeness and the maximum magnitude are obtained for each seismic source based on the *ROMPLUS* catalogue (http://www.infp.ro/catalog-seismic) revised in the framework of the *SHARE* Project using the methods proposed in (Zuniga & Wyss, 1995, Wiemer & Wyss, 2000) and in (Kijko, 2004), repectively. The *a* and *b* seismicity parameters are obtained for all the seismic sources through maximum likelihood method (McGuire, 2004).

The ground motions prediction equations (GMPEs) initially considered for the probabilistic seismic hazard analysis for Vrancea intermediate-depth seismic source are the ones given in (Delavaud et al., 2012), where four GMPEs selected within the SHARE regional project of Global Earthquake Model (GEM) are recommended for Vrancea subcrustal seismic source: (Zhao et. al., 2006), (Atkinson & Boore, 2003), (Youngs et. al., 1997) and (Lin & Lee, 2008). Besides these GMPEs, the ground motion prediction model proposed in (Vacareanu et al., 2013b) for intermediate-depth earthquakes and average soil conditions is used for the analysis of the seismic hazard. The

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GMPEs are applied with different weights in the fore-arc region of Romania (to the east and to the south with respect to the Carpathians Mountains) and in the back-arc region (to the north and to the west with respect to the Carpathians Mountains). The grading of the GMPEs is performed according to the ranking procedure given in (Scherbaum et al, 2004). The overall analyses are presented in (Vacareanu et al., 2013a and Pavel et al., 2014). For the crustal seismic sources the GMPEs of (Cauzzi and Faccioli, 2008), (Akkar and Bommer, 2010) and (Idriss, 2008) are considered..

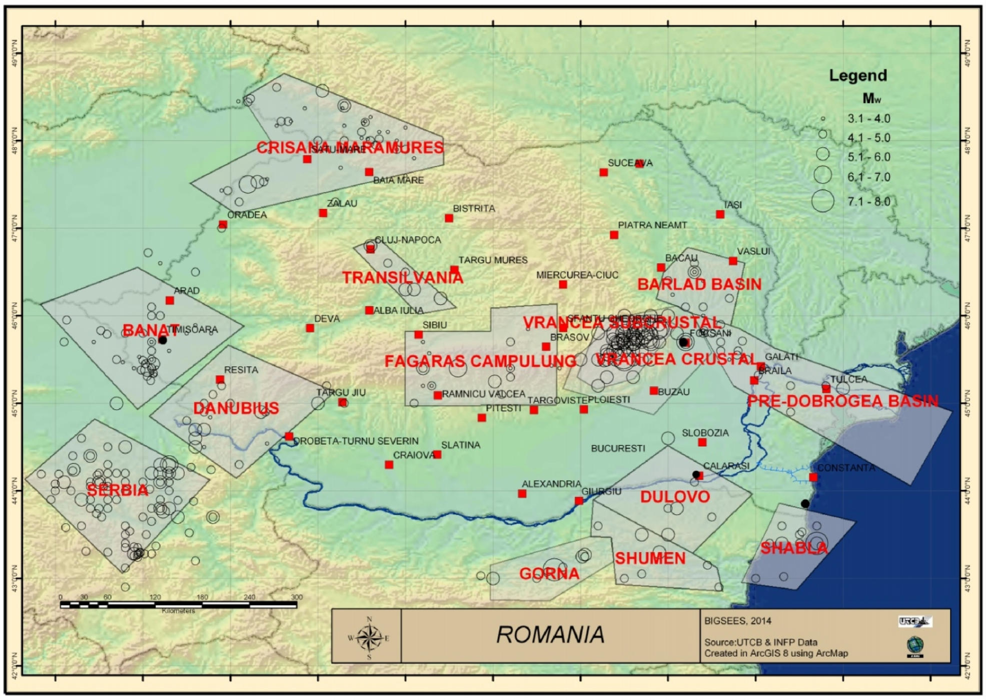

Figure 1. Sources contributing to the seismic hazard of Romania (Vacareanu et al., 2014)

The logic tree used in this study for incorporating into PSHA the epistemic uncertainties aggregates altogether the crustal and subcrustal seismic sources as well as the situations when a given site is situated in the fore-arc or back-arc region with respect to Vrancea subcrustal seismic source. The weighted branches of the logic tree refers to catalogue duration and maximum magnitude for Vrancea intermediate-depth seismic source and to the GMPEs used in PSHA for all the seismic sources. The weights for the catalogue duration and maximum magnitude are based on expert judgment. The weights for the GMPEs are based on goodness-of-fit indicators and are detailed in (Pavel et al., 2014).

The Probabilistic Seismic Hazard Analysis (PSHA) for Romania is performed using the methodology given in (Cornell, 1968; Reiter, 1990; McGuire 1999 & 2004; Kramer, 2005). The PSHA was performed for peak ground acceleration and spectral accelerations at periods T = 0.2s; 0.4s; 1.0s; 2.0s and 3.0s. The selected spectral periods are common for all the GMPEs used in the analysis. Some results of the PSHA for Romania are presented in a concise form in Figure 2. The seismic hazard maps for peak ground acceleration and spectral acceleration for T = 0.4 s with 10% exceedance probability in 50 years are given in Figure 2, considering the aggregate contribution of all the seismic sources included in the analysis.. The strong influence of Vrancea intermediate-depth seismic source for the S-E of Romania is obvious. The contribution to the seismic hazard of the seismic sources situated in N-E of Bulgaria and of the Fagaras-Campulung and Transilvania seismic sources is noticeable from Figure 2.

The results presented in this paper are obtained within the framework of BIGSEES national research project (http://infp.infp.ro/bigsees/default.htm) and represents a preliminary outcome. For the time being these results represent the best estimate for the seismic hazard and are based on the largest database of earthquakes and strong ground motions and on the state-of -the-art approaches. The final seismic hazard maps will be released by the end of the project and will represent a harmonized product aimed at bridging the narrowing gap between seismology and earthquake engineering in Romania.

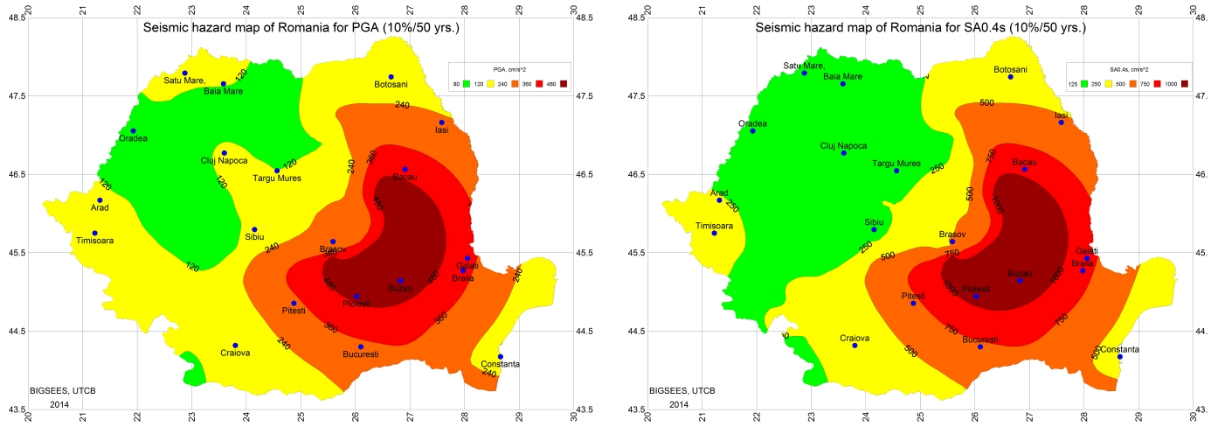

Figure 2. Seismic hazard maps of Romania (Vacareanu et al., 2014). The results are given as peak ground acceleration (left) and spectral acceleration for $T = 0.4$ s (right) with 10% exceedance probability in 50 years. The contribution to seismic hazard of all seismic sources that influence the Romanian territory is considered

ACKNOWLEDGMENTS

Funding for this research was provided within BIGSEES Project by the Romanian Ministry of National Education under the Grant Number 72/2012. This support is gratefully acknowledged.

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