

## Next Future Large Earthquake in Romania: A Disaster Waiting to Happen?

### GENERAL INFORMATION

Romania has one of the highest seismic-hazard levels in Europe. The recent study by Pavel *et al.* (2016) shows that around two-thirds of the country (over 150,000 km<sup>2</sup>) has an expected peak ground acceleration in excess of 0.2g (value with 10% probability of exceedance in 50 years). In this article, the possible impact and the institutional response in the event of a future large earthquake are discussed in the light of a several recent events and studies.

### BRIEF INFORMATION REGARDING THE SEISMICITY OF ROMANIA

Romania is mainly affected by earthquakes occurring in the Vrancea intermediate-depth seismic source. Nevertheless, large magnitude crustal earthquakes can occur in several locations throughout Romania. The 1916 Fagaras earthquake, with an estimated moment magnitude ( $M_w$ ) of 6.4, was the largest crustal earthquake that occurred in Romania in the twentieth century. It struck mainly an uninhabited area, and thus its impact was limited (descriptions of its effects are also very limited). However, the experience and the information gathered from other shallow earthquakes in 1981 (an earthquake with  $M_w$  5.1, and focal depth  $h$  of 15 km near the Danube Delta), in 1991 (three earthquakes in the western part of Romania with magnitudes  $M_w$  5.5), and in 2014 (a  $M_w$  5.4 and  $h = 41$  km earthquake in the Vrancea region) have shown that this type of earthquake can cause significant structural damage, panic, and even casualties. The recent experience of the Lorca earthquake in Spain (2011) with regard to structural damage and losses due to a relatively small magnitude shallow-focus earthquake ( $M_w$  5.1) occurring close to a densely populated area is also worth considering (Hermans *et al.*, 2014).

Other likely candidates for a potentially destructive local crustal earthquake include (Bala *et al.*, 2015) the Transylvania seismic source that has not generated any significant earthquake ( $M_w > 5.0$ ) since 1880 and is situated beneath Cluj-Napoca (second most populous city in Romania), the Crisana-Maramures seismic zone that generated its last  $M_w > 5.0$  shock more than 50 years ago (over the border in Ukraine) and covers almost three

counties in the northwestern part of Romania, and the Fagaras-Campulung seismic zone that has also yielded its last  $M_w > 5.0$  earthquake around 50 years ago. The latter is situated near the epicenter of the 1916 Fagaras earthquake and is close to both Sibiu and Brasov as well as to numerous water-retaining works (including Vidraru Dam with a height of over 160 m and a lake volume of almost 0.5 km<sup>3</sup>).

### IMPACT OF VRANCEA EARTHQUAKES

Nevertheless, the likely impact upon the built environment of an earthquake in one of these crustal seismic sources is much less than the potential impact of a future large earthquake in the Vrancea intermediate-depth seismic source. Wenzel *et al.* (2002) notes that Vrancea earthquakes “pose a geologic hazard to Romania and adjacent countries that is comparable to the hazard the recently devastated area of Izmit in Turkey (17 August 1999, moment magnitude of 7.6) is exposed to.” The impact of such an earthquake could be catastrophic for Bucharest, the capital city of Romania, where 25% of the national gross domestic product (GDP) is generated.

The Vrancea intermediate-depth seismic source has generated two major earthquakes in the past century. The shocks of November 1940 with a moment magnitude  $M_w$  7.7 and a presumed focal depth of 150 km and the subsequent event of March 1977 ( $M_w$  7.4 and focal depth  $h = 94$  km) caused widespread damage and casualties (between 500 and 1000 deaths in the case of the 1940 earthquake and 1578 deaths in the subsequent earthquake; Georgescu and Pomonis, 2012). Georgescu (2008) argued that the 1977 earthquake contributed extensively to the serious economic crisis that began in Romania in 1979 and lasted even after 1989. The subsequent shocks of August 1986 and May 1990 have caused additional structural damage. In this context, the decision taken by the Romanian Government in the aftermath of the March 1977 earthquake to impose strengthening of buildings to the level they had prior to the earthquake has led to a tremendous seismic vulnerability issue (Lungu *et al.*, 2000). For a better understanding of this vulnerability issue, one has to take into account that prior to 1977, the spectral shape used for seismic design of structures had a constant acceleration plateau extending only up to 0.3 or 0.4 s. Thus, long-period amplifications were disregarded. However, the seismic recordings from the 1977 and 1986 Vrancea earthquakes also contained significant long-period amplifications and thus exceed

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the code spectral shape by several times. As a consequence, the buildings built before 1977 and that suffered damage during the 4 March earthquake were designed for a seismic loading that was much smaller than required (due to the lack of medium- and long-period spectral amplifications) and were strengthened after 1977 to the same level of lateral strength as was used for their original design. Nevertheless, the March 1977 event did lead to vast changes in the building design regulations. Hence, the buildings constructed in the aftermath of this event can be considered much safer than the ones built before, because the new spectral shape took into account the long-period spectral amplifications revealed by the analysis of the 1977 recording in Bucharest.

Based on some characteristics of Vrancea earthquake activity, previous studies were successful to some extent in the long-term forecasting of the 1977  $M_w$  7.4 Vrancea earthquake (Enescu *et al.*, 1974; Purcaru, 1974; see also the discussion of Hurukawa *et al.*, 2008). Attempts to forecast the next large Vrancea earthquake indicated time intervals of increased probabilities in 2006–2011 (Enescu and Enescu, 1999) or 2005–2010 (Imoto and Hurukawa, 2006). One may speculate that a large Vrancea event is due (or overdue), but such results should be interpreted with caution, given the uncertainties that usually accompany such long-term estimates and the difficulty of testing the reliability of the underlying statistical models.

## ISSUES RELATED TO EMERGENCY RISK MANAGEMENT

The main institution responsible for emergency situations (including earthquakes) in Romania is the General Inspectorate for Emergency Situations. Funding for this Institution lies in the region of 0.20% of the GDP of Romania (the highest percentage of 0.25% occurred in 2014). In 2016, a 25% cut with respect to the 2015 budget was envisaged (see [Data and Resources](#)). According to a brochure published by the General Inspectorate for Emergency Situations, they have roughly 30,000 employees spread throughout the country in 43 operational centers (see [Data and Resources](#)). The Romanian army played a major role in the rescue and debris clearance operations after the 1977 earthquake. The debris clearance and reconstruction works also involved the army and proved extremely successful, as shown by a World Bank Report (World Bank, 1978). In addition, permanent housing solutions in new apartment blocks were found for most of the affected people. Nowadays, the entire Romanian army numbers fewer than 80,000 people, with far less construction-related equipment than 40 years ago.

Around a quarter of the population of Romania has not experienced any Vrancea earthquake with a magnitude  $M_w \geq 6.0$  and more than 40% did not experience the devastating 1977 event. A recent survey for which results have not been published yet was performed within the framework of the COBPEE research project (see [Data and Resources](#)) reveals some interesting facts. Even though over 40% of the respon-

dents (over 900 individuals took part in the survey) claim that they are familiar with the *Citizen Guide for Emergency Situations* prepared by the General Inspectorate for Emergency Situations, only 5% of the respondents have an emergency bag (containing vital things for 3–5 days following an earthquake) in their homes and fewer than 10% have specialized first-aid training.

The Colectiv nightclub fire from October 2015 (see [Data and Resources](#)) claimed the lives of 64 people and exposed major problems with the healthcare system in Romania. According to data from the National Statistics Institute (see [Data and Resources](#)) Bucharest has twice the number of doctors per 1000 inhabitants as the rest of the country, and that there are nine emergency hospitals (out of 51 healthcare units), but the difficulties in treating around 200 injured people (albeit many of them had serious burns) can only leave us to wonder what will happen in the case

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of a major earthquake when the affected territory will be much larger. If one considers also the fact that many of the deaths from the Colectiv nightclub fire were due to hospital-related infections, the problem of properly treating earthquake casualties becomes even more complicated. Besides these issues, one has to take into account that in some counties, as exposed to Vrancea earthquakes as Bucharest, the number of doctors is three to four times smaller, and the most important emergency medical units are situated in the county capital. The experience of the Vrancea earthquakes of 1977 and 1986 ( $M_w$  7.1 and  $b = 131$  km) during which buildings collapsed in Bulgaria and in the Republic of Moldova is relevant for the large regions affected by this type of events (Alkaz, 1999; Georgescu and Pomonis, 2012). Another interesting aspect observed after the Colectiv disaster is the related country-wide social unrest that led to the resignation of the Romanian Government.

Finally, the program of seismic strengthening of buildings appears to be finally gaining some momentum, because the budget for 2016 (around 6 million euros) is five times larger than that for 2015 (see [Data and Resources](#)). Nevertheless, according to the figures given by the Municipality of Bucharest, only 75 buildings (most of them low-rise buildings) have been strengthened in the past 20 years.

## FINAL REMARKS

The future large earthquake that will strike Romania (either crustal or intermediate depth) will pose great challenges to the existing building stock due to the measures taken in the aftermath of the March 1977 seismic event, as well as due to the poor state of many of the old buildings in general (including schools, hospitals, cinemas, etc.). In addition, it will affect a population that does not appear to be prepared for such an event, and it will test the response of the General Inspectorate for Emergency Situations which has funding that is around

0.20% of the national GDP. Finally, it will create even more problems for the national healthcare system and will likely generate social unrest with an impact difficult to foresee. Several suggestions to improve this situation might be:

- a drastic increase in funding for the General Inspectorate for Emergency Situations;
- training of volunteers for search and rescue operations at a community level;
- implication of the local community in a national program aimed at informing the people on seismic risk issues;
- an increase of funding for the national program for strengthening buildings focusing especially on schools, hospitals, and other public buildings; and, finally
- transferring the responsibility for strengthening of buildings from the Government to the dwelling owners.

## DATA AND RESOURCES

All data used in this article came from published sources listed in the references. Budget of the General Inspectorate for Emergency Situations can be found at [http://www.igsu.ro/documente/Buget/buget\\_2010-2016.pdf](http://www.igsu.ro/documente/Buget/buget_2010-2016.pdf) (last accessed July 2016). A brochure of the General Inspectorate for Emergency Situations can be found at [http://www.igsu.ro/documente/SAEARI/BROSURA\\_IGSU\\_RO.pdf](http://www.igsu.ro/documente/SAEARI/BROSURA_IGSU_RO.pdf) (last accessed July 2016). The COBPEE Research Project is available at [http://cobpee.utcb.ro/index\\_en.html](http://cobpee.utcb.ro/index_en.html) (last accessed July 2016). Colectiv nightclub fire information is available at <http://www.bbc.com/news/world-europe-34684973> (last accessed July 2016). A list of strengthened buildings in Bucharest can be found at [http://www.pmb.ro/servicii/alte\\_informatii/lista\\_imobilelor\\_exp/docs/Lista\\_imobilelor\\_expertizate.pdf](http://www.pmb.ro/servicii/alte_informatii/lista_imobilelor_exp/docs/Lista_imobilelor_expertizate.pdf) (last accessed July 2016). The ROMPLUS catalog is available at <http://www.infp.ro/wp-content/uploads/2015/12/romplus.txt> (last accessed July 2016). The information on the 2016 budget can be found at <http://www.mdrap.ro/comunicare/presa/comunicate/80-de-cladiri-cu-bulina-incluse-in-2016-in-programul-privind-reducerea-riscului-seismic-la-locuintele-multietajate> (last accessed July 2016). ☒

## ACKNOWLEDGMENTS

This work was supported by a grant of the Romanian National Authority for Scientific Research and Innovation, Consiliul National al Cercetarii Stiintifice–Unitatea Executiva pentru Finantarea Invatamantului Superior, a Cercetarii, Dezvoltarii si Inovarii (CNCS–UEFISCDI), Project Number PN-II-RU-TE-2014-4-0697. The financial support is gratefully acknowledged. The constructive feedback from Editor-in-Chief Zhigang Peng and from one anonymous reviewer is greatly appreciated, because it has led to a much improved version of the article. I also thank John Douglas for proofreading the revised version.

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Published Online 2 November 2016