Bulgarian Chemical Communications, Volume 47, Special Issue B (pp. 390–396) 2015

System of Earthquakes Alert (SEA) in the Romania-Bulgaria cross border region

L. Dimitrova*, D. Solakov, S. Simeonova, I. Aleksandrova

National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Acad. G. Bonchev Str., Bl.3, BG-1113 Sofia, Bulgaria

Among the many kinds of natural and man-made disasters, earthquakes dominate with regard to their social and economical impact on the urban environment. The prevention of the natural disasters and the performing management of reactions to crisis are common problems for many countries. The main objective of this study is to present the integrated warning system that was designed and put in operation in the Romania-Bulgaria cross-border area in the framework of DACEA (Danube Cross-border System for Earthquake Alert) project. The main goals of the implemented system are: monitoring of the seismogenic areas relevant for the cross-border area, in order to detect moderate to strong earthquakes and sending the seismic warning signals within seconds to the local public authorities in the cross-border area.

Key words: seismicity, intermediate-depth, earthquakes, seismic sources, warning systems, Romania-Bulgaria cross border region

INTRODUCTION

The cross-border region encompassing northern Bulgaria and southern Romania is a territory prone to effects of strong earthquakes. Romania and Bulgaria, situated in the Balkan Region as a part of the Alpine-Himalayan seismic belt are characterized by high seismicity, and are exposed to a high seismic risk. Over the centuries, the two countries experienced strong earthquakes. The considered cross-border region is significantly affected by earthquakes occurred in both territories on the one-hand, Vrancea seismic source (in Romania), with intermediate-depth events and on the other hand, crustal seismicity recorded in the northern part of Bulgaria (in seismic sources: Shabla, Dulovo, Gorna Orjahovitza).

The spatial pattern of seismicity in the cross border region and adjacent areas is shown in Fig. 1.

The Vrancea seismogenic zone in Romania is a very peculiar seismic source, often described as unique in the world, and it represents a major concern for most of the northern part of Bulgaria as well. Situated at distances larger than 200 km from the Vrancea zone, several cities in the northern Bulgaria suffered many damages due to high energy Vrancea intermediate-depth earthquakes; the March 4, 1977 event ($M_w7.2$) caused partial or total damages to 8470 buildings, and 125 casualties on the territory of Bulgaria (as illustrated in Fig. 2).

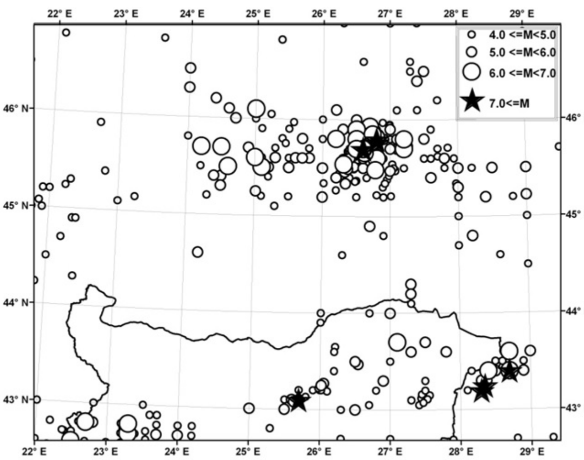

Fig. 1. Spatial distribution of seismicity (historical and instrumental $M_w \geq 4.0$) in Romania-Bulgaria cross-border region.

DACEA PROJECT

The project DACEA is implemented in the framework of the Romania–Bulgaria Cross Border Cooperation Programme (2007-2013), co-financed by the European Union through the European Regional Development Fund, the Bulgarian and Romanian Governments and the 5 project partners. DACEA project general objective is to develop a cross-border system for Earthquake alerts in order to prevent the natural disasters caused by those events in the cross-border area, taking into account the nuclear power plants and other high risk facilities located along the Danube on the territories of Romania and Bulgaria. The most important factor for a rapid action after a destructive earthquake is the real-time communication with the seismic sensors in the closer epicenter area and with

* To whom all correspondence should be sent: ldimitrova@geophys.bas.bg

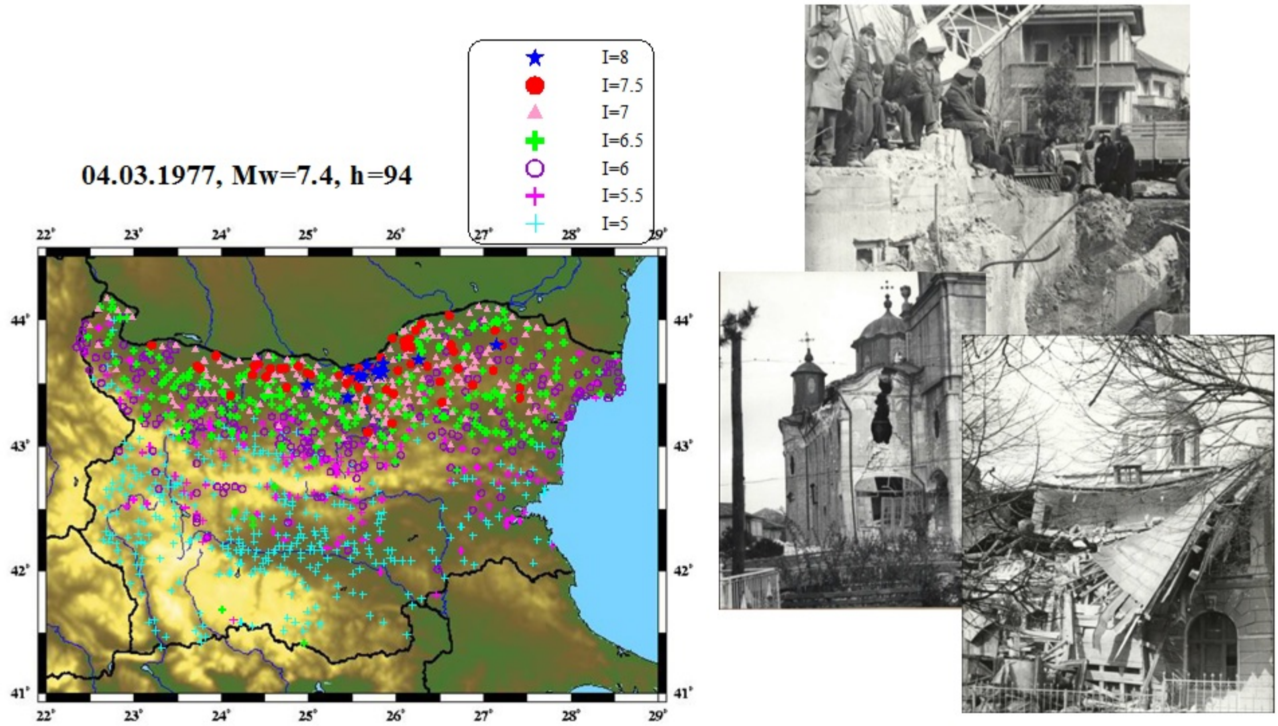

Fig. 2. The 1977 Vrancea earthquake effects on the territory of Bulgaria (modified from [1]).

dense station networks towards and within vulnerable cities and industrial plants. This will provide fast and reliable information for the near real-time hypocenter determination and the automated construction of Shake maps of the ground motions. A fast overview of an anticipated damage pattern will then be possible using this information. The project Danube Cross-border System for Earthquake Alert (DACEA) contributes significantly to these challenges.

As a principal strategic view, the first part of the project was focused on updating and integrating the current databases available at the two countries related to geological, seismological and tectonic information and on integration of computation procedures and techniques. A database for integration of the detailed information that was compiled for the Romania-Bulgaria Cross-border region is designed and implemented. Model of the compiled Data Base (DB) as a *UML* diagram is presented in Fig. 3.

The second part of the project activities was connected with the seismic hazard assessment for Romania-Bulgaria cross-border region on the basis of integrated basic geo-datasets. The hazard estimates are to be considered as a crucial phase of the risk management cycle associated with hazards (mitigation and preparedness, early warning, response, and recovery). The *MSK*64 intensity is used as output parameter for the hazard maps. A particular advantage of using intensities is that the very irregular pattern of the attenuation field of the Vrancea intermediate depth earthquakes (for example, as it is illustrated in [2]) can be estimated from detailed macroseismic observations that are available (in both countries) for the study region. The seismic hazard analysis was performed by carrying out the following steps: analysis of the seismic, geophysical and geological features; compilation of the seismic source model; hazard assessment for the target region; and producing of the hazard maps. The hazard results (presented in [3]) are obtained by applying two alternative approaches - probabilistic and deterministic. The probabilistic hazard map in intensity scale for return period of 475 (probability of exceedance of 10% in 50 years) is presented in Fig. 4.

The seismic hazard for a return period of 475 years (Fig. 4) displays nearly the same intensity level as previous hazard estimates (for example, presented in [2], [4], [5]) that were obtained using different approaches to simulate the observed attenuation field

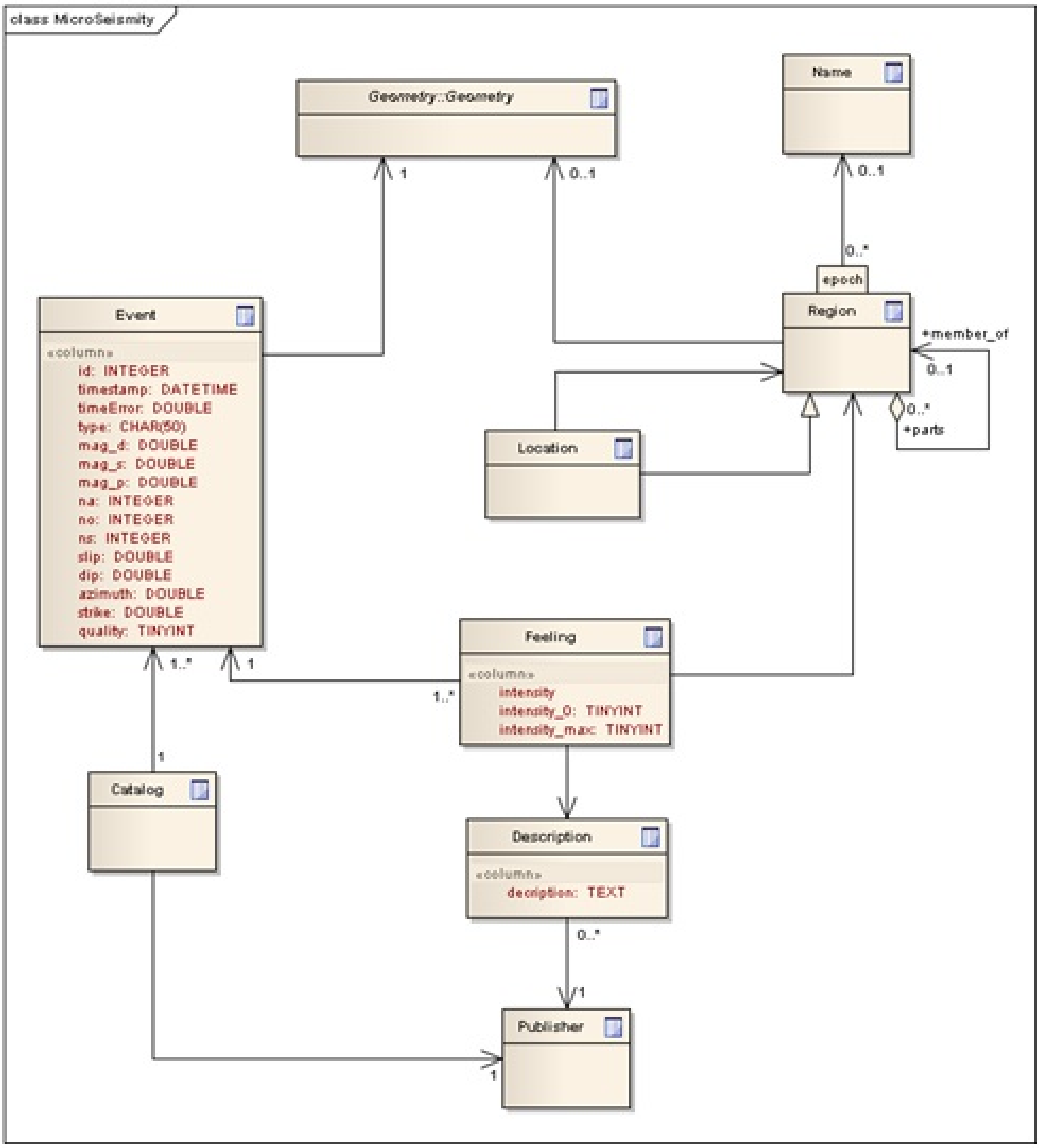

Fig. 3. Data Base model.

(for both shallow and subcrustal events), and source models mainly based on the spatial distribution of the seismicity. At the third step of the DACEA project - the most appropriate station sites were selected and studied - low level of noise was the most important requirement (Fig. 5). The method of McNamara and Bulland [6] was applied to evaluate ambient seismic noise at the potential sites. This method has been used for evaluation of the seismic noise and estimation of the performance of the broadband seismic stations belonging to Bulgarian national seismic network [7]. The advantage of the method is that there is no need

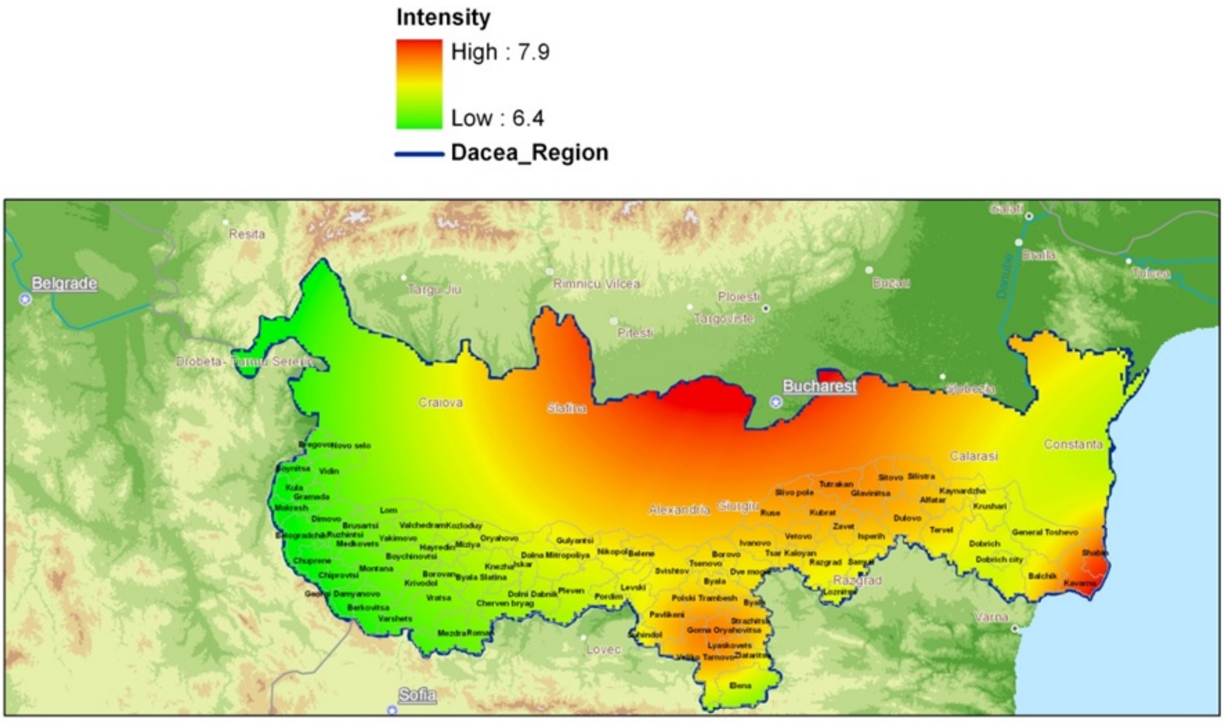

Fig. 4. Seismic hazard map for the cross-boarder region for 475 years return period (modified from [3]).

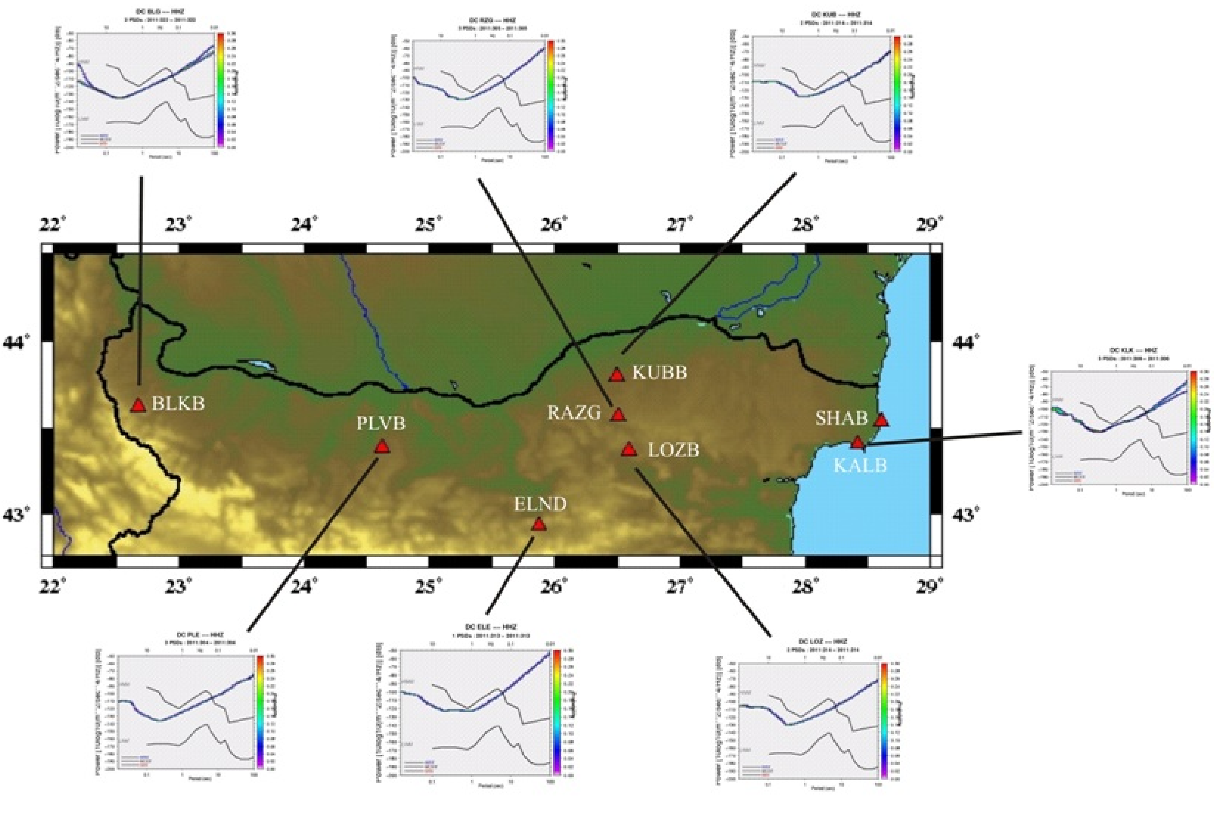

Fig. 5. Ambient seismic noise at the selected sites.

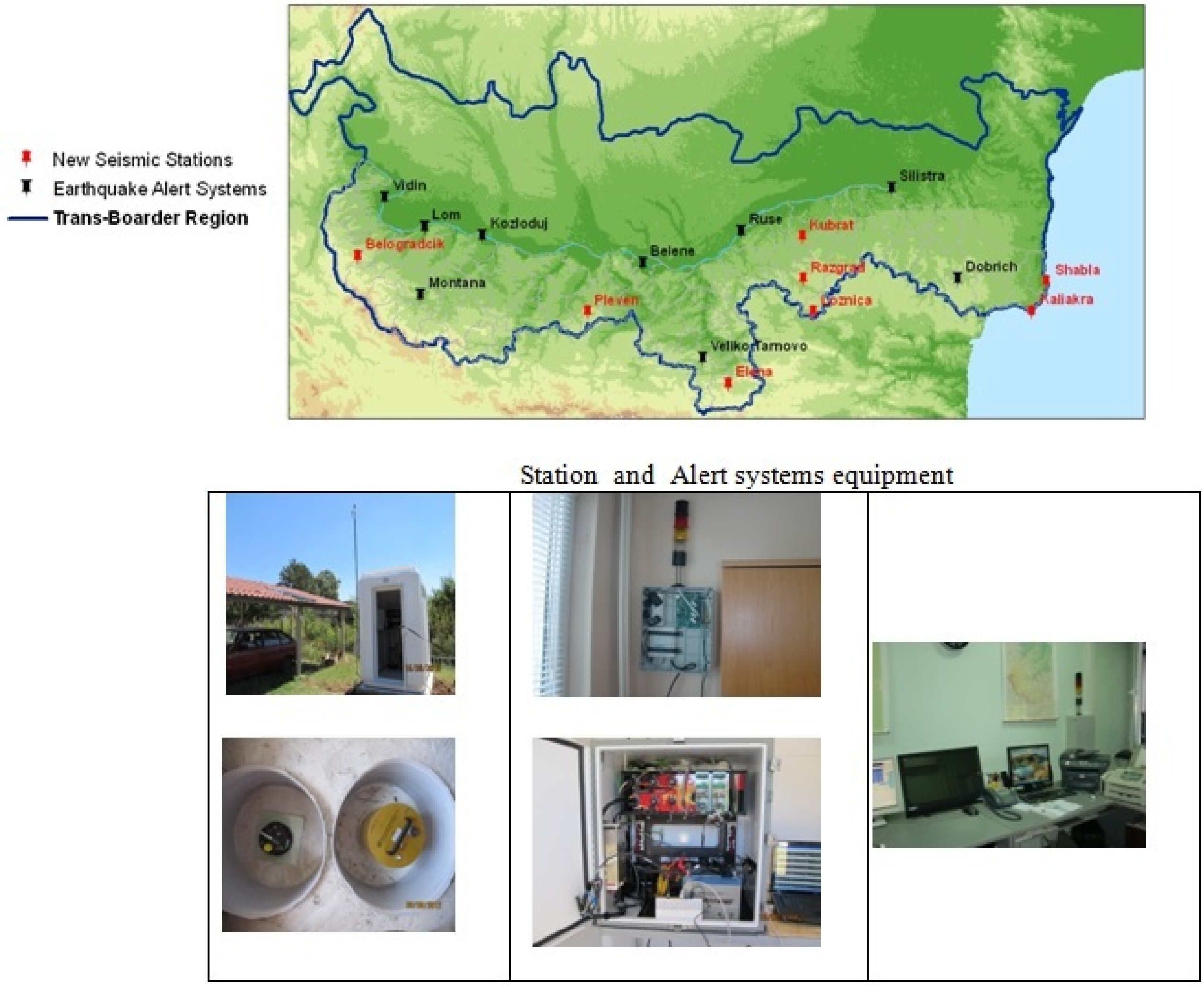

Fig. 6. Configuration and equipment of SEA on the territory of Bulgaria.

to filter data from earthquakes, gaps, spikes, calibrations pulses etc. Such kind of signals has low-level of occurrence while ambient noise reveals itself as a signal with high probability occurrence. The total power spectral density (PSD) is given by the following expression:

$$P_k = \frac{2\Delta t}{N} \mid Y_k \mid^2, \qquad (1)$$

where Y_k is the square of the amplitude spectrum with a normalization factor of $2\Delta t/N$, Δt is the sample interval, N is the number of samples in a time series segment and $k = 1, 2, ..., N-1$. The seismic noise is measured in respect to the ground acceleration. The PSD of the noise is also displayed against the ground acceleration. The equation of the PSD in unit of dB is

$$PSD = 10 \log_{10}(m^2/sec^4)/Hz[dB] \qquad (2)$$

SYSTEM OF EARTHQUAKES ALERT (SEA)

The installed System of Earthquakes Alert (SEA) involves 8 seismic stations and 8 earthquake alert systems on the territory of Northern Bulgaria. Configuration and equipment of the stations and earthquake alert systems is presented in Fig. 6.

The installation and maintenance, as well as the data-processing are performed in close cooperation with the leading partner – National Institute for Earth Physics (NIEP), Bucharest, Romania. The aim of the installed system is to provide an early warning alert and a rapid damage assessment to the emer-

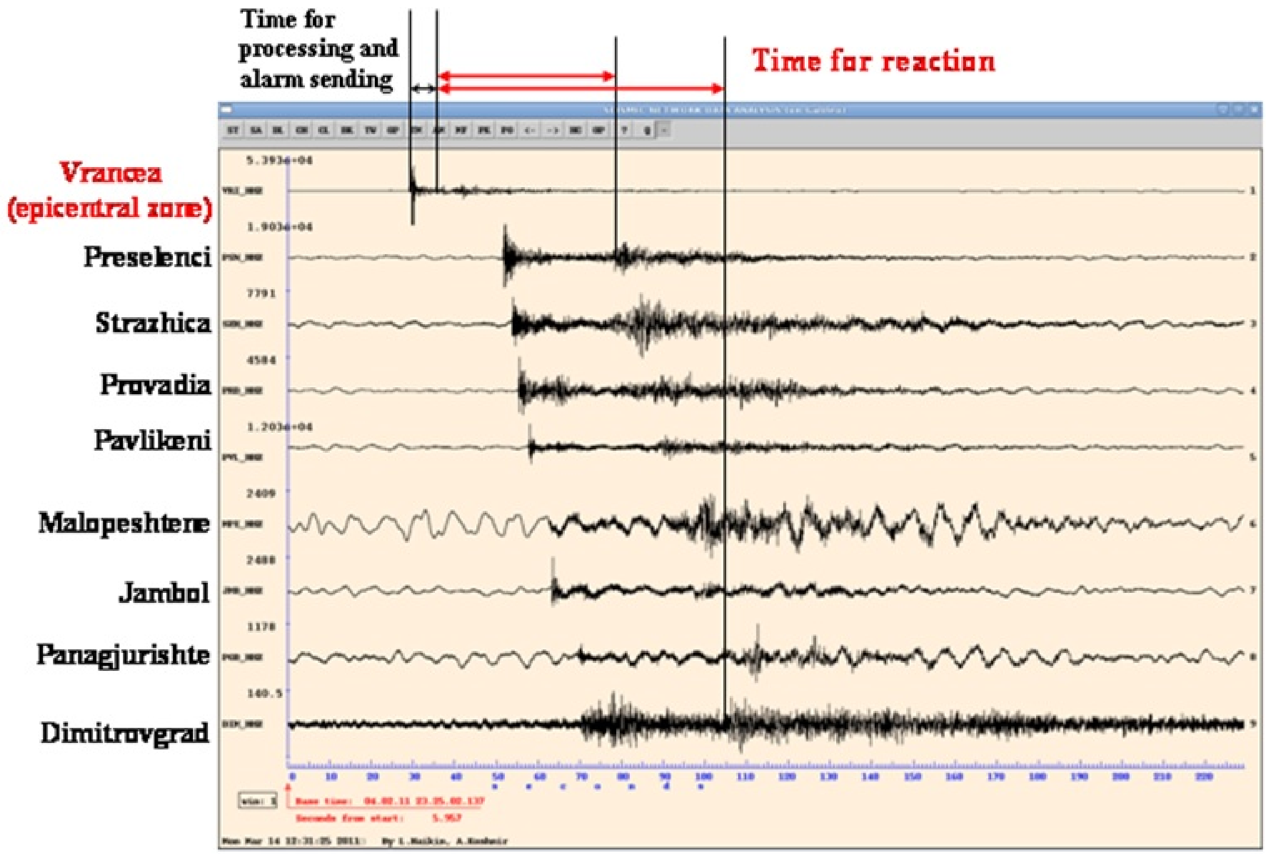

Fig. 7. Response time for several sites on the territory of Bulgaria after Vrancea earthquake.

gency management agencies immediately after a major seismic event. The system performs *P*-waves arrival detection and, once an event has been detected, it first provides location and magnitude estimations. The earthquake location is obtained through real-time probabilistic approach based on an equal differential time formulation that uses information from both triggered and not-yet-triggered stations. The earthquake magnitude is estimated exploiting its empirical correlation with the peak displacement measured on the first 2-4s of *P*-waves. All estimates are provided as probability density functions, with an uncertainty that typically decreases with time, and can be sent as alarm messages that can reach the vulnerable structures before the arrival of destructive *S*-waves. Fig. 7 shows the response time (for several sites on the territory of Bulgaria) after Vrancea earthquake.

Finally, SEA centers were established both in Sofia (in National Institute of Geophysics, Geodesy and Geography) and Bucharest (in National Institute of Research and Development for Earth Physics, NIEP). Real time data transfer (via internet) from stations to SEA centers is implemented. Both centers are equipped with servers for data analyses and storage. Specialized software for elaboration of scenarios of seismic hazard is designed and implemented. The software is designed on the base of the compiled data base of historical and contemporary seismicity in the cross-border region. The output shake maps and scenarios are to be used by the emergency intervention units, local public authorities and for general public awareness.

REFERENCES

[1] D. Solakov, (Ed.), *Project report: "'Microseismic zoning of Bulgaria according to EC8", Sofia, Geophysical Inst., BAS*, p. 205, (2007).

[2] G. Leydecker, H. Busche, K. P. Bonjer, T. Schmitt, D. Kaiser, S. Simeonova, D. Solakov, and L. Ardeleanu, *Nat.Hazards Earth Syst. Sci.*, 8, 1431-1439, (2008).

[3] D. Solakov, S. Simeonova, L. Ardeleanu, I. Alexandrova, P. Trifonova, C. Cioflan, *Com. Rend. de L'Acad. Bulg. des Sci.*, accepted, (2014).

[4] L. Ardeleanu, G. Leydecker, H. Busche, T. Schmitt, and D. Kaiser, *Nat. Hazards Earth Syst. Sci.*, 5, 679-684, (2005).

[5] S. Simeonova, D. Solakov, G. Leydecker, H. Busche, T. Schmitt and D. Kaiser, *Nat. Hazards Earth Syst. Sci.*, 6, 881–887, (2006).

[6] E. McNamara and P. Buland, *BSSA*, 94, 1517-1527, (2004).

[7] L. Dimitrova, S. Nikolova, *Bulgarian Geophysical Journal, Vol. 37*, pp. 48-61, (2011)

СИСТЕМА ЗА РАННО ОПОВЕСТЯВАНЕ НА ЗЕМЕТРЕСЕНИЯ В ТРАНС-ГРАНИЧНИЯ РАЙОН РУМЪНИЯ–БЪЛГАРИЯ

Л. Димитрова, Д. Солаков, С. Симеонова, И. Александрова

Национален институт по геофизика, геодезия и география, Българска академия на науките, ул. "Акад. Г. Бончев" бл.3, 1113 София, България

(Резюме)

В сеизмично активните райони на планетата, включително и в България, земетресенията и последствията от тях са най-катастрофалните природни бедствия. Обяснението е в спецификата на явлението земетресение – краткотрайно и силно въздействие с изключително не хуманни последствия върху значителни по площ територии. Последствията са изключително тежки особено, когато в засегнатите райони са съсредоточени големи човешки и материални ресурси. Превантивните мерки по отношение на природните бедствия и управлението на дейностите по време на кризи са глобален проблем. Проектът "Дунавска транс гранична система за ранно оповестяване на земетресения" (Danube Cross-border System for Earthquake Alert (DACEA)), реализиран в рамките на Програмата за транс гранично сътрудничество между Румъния и България (2010-2013), предоставя възможност за намаляване на последствията от силни земетресения.

Териториите на Румъния и България, като част от Алпо-Хималайския сеизмичен пояс, се характеризират с висока сеизмичност. Двете държави са изложени на висок сеизмичен риск. Транс-граничният регион, включващ южна Румъния и северна България, е подложен на въздействието от сеизмични източници, разположени на Румънска територия, каквото е огнище Вранча, така и на тези намиращи се на територията на България – Дулово, Шабла, Горна Оряховица. В изпълнение на проекта в транс-граничния район е изградена съвместна мрежа от еднотипни сеизмични станции с реално времева връзка с центровете за обработка на сеизмологичната информация. Реално времевата комуникация е важен фактор, който в голяма степен влияе върху бързината на реакция след силни земетресения. Осигурява се бърза и надеждна информация за местоположението и силата на земетресенията, автоматично съставяне на карти на сътресяемост и оценка на възможните разрушения и човешки загуби. Тази информация може да се използват от звената на ГД ПБЗН и местните администрации, за предприемане на необходимите мерки за защита на населението и намаляване на последствията от земетресението.

Изградени са два сеизмични центъра – в София (в Национален институт по геофизика, геодезия и география към БАН) и в Букурещ (в Националния институт по физика на Земята). Двата центъра са оборудвани със сървъри за анализ и съхранение на данните. Разработен и инсталиран е специализиран софтуер за изготвяне на карти на сътресяемост. Софтуерът е разработен на базата на богата база данни от исторически и съвременни земетресения, реализирани в транс-граничните територии.