THE PERFORMANCE OF THE STATIONS OF THE ROMANIAN SEISMIC NETWORK IN MONITORING THE LOCAL SEISMIC ACTIVITY. PART II. NORMAL DEPTH EVENTS

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Abstract. A primary objective of the national seismic network operated by the National Institute for Earth Physics of Bucharest is the monitoring of the seismic activity on the territory of Romania. As a result of a considerable effort carried out during the past years, mainly since 2008, the network consists at present of 118 permanent digital stations – 99 stations with real time data transmission and 19 off-line stations – distributed over the whole territory of the country. The goal of this study is to evaluate the contribution of the on-line network stations to the monitoring of the local normal depth seismicity. During the period January 1, 2008 – June 30, 2013, 5933 events with depth < 60 km and local magnitude $M_L \geq 1.2$ – earthquakes and quarry blasts – have been localized within the Romanian borders, or in their immediate vicinity, using the data of the national network. To estimate the effectivity of the individual stations we take into consideration the fraction of events localized using the station records (compared to the total number of events of the catalogue, which occurred during the time of station operation), and the location of the station site with respect to the shallow depth seismic sources. The analysis provides a measure of the overall network performance regarding the monitoring of the local seismic activity, and allows us to quantify the value of the individual stations for the localization of the seismic events on the territory of Romania; this information is crucial for decisions regarding the effectiveness increasing and future development of the national network.

Key words: Romanian seismic network, real time seismic stations, normal depth seismic events, network performance, seismic station effectiveness.

1. INTRODUCTION

The continuous monitoring of the seismic activity on the entire national territory is a primary objective of the seismic network operated by the National Institute for Earth Physics of Bucharest.

The considerable effort carried out during the past years, mainly since 2008, in order to upgrade and develop the network (Table 1), resulted in 118 permanent digital stations in operation at present, distributed over the whole territory of the
country – 99 stations with real time data transmission and 19 off-line stations. All stations are equipped with 3-component accelerometers, while most of the on-line stations comprise in addition velocity sensors. Detailed information on instruments, as well as data transmission, acquisition and processing software is given in [5] and [6].

Apart from the source of strong intermediate depth earthquakes located at the bend of Eastern Carpathians, several seismogenic areas of local importance for the seismic hazard are also present in the crust, in western (Crişana – Maramureş, Banat, Danubian zones), central (Făgăraş – Câmpulung zone, Transylvanian depression) and eastern Romania (Vrancea normal depth zone, Bărlad and Predobrean depressions, Intramoesian Fault). Descriptions of these shallow depth sources – boundaries, seismicity characteristics – are given in several studies (e.g. [1, 2, 3, 4]).

<table>
<thead>
<tr>
<th>Table 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>The recent development of the Romanian seismic network</td>
</tr>
<tr>
<td>Stations in operation at present</td>
</tr>
<tr>
<td>Stations installed/ upgraded during the period 2008–2013</td>
</tr>
<tr>
<td>98</td>
</tr>
</tbody>
</table>

The goal of our work is to evaluate the performance of the network, in its present configuration, regarding the monitoring of the seismic activity on the territory of Romania. In this second part of the analysis we examine the contribution of the on-line stations in operation at January 1, 2013, to the localization of the normal depth seismic events which occurred during the period January 1, 2008 – June 30, 2013.

During the study time interval, 5933 events with depth < 60 km and local magnitude $M_L \geq 1.2$ – earthquakes and quarry blasts – have been localized within the Romanian borders, or in their immediate vicinity (ROMPLUS earthquake catalogue [7], updated); 853 events occurred in 2008, 830 events in 2009, 1044 events in 2010, 1258 events in 2011, 1231 events in 2012, and 717 events during the first 6 months of 2013. The locations of the events were computed by HYPOPLUS program [8], using an average velocity model for the lithosphere [7].

Figure 1 displays the space distribution of the events. More than 60% of them are located within the uppermost 10 km, while less than 5% exhibit depths greater than 30 km. The largest earthquake occurred offshore (beneath the bottom of the Black Sea) on May 7, 2008, and had local magnitude 5.7.

The histogram of magnitudes (Fig. 2) shows that most of the localized events are weak, with $M_L$ in the range 1.9 to 2.6; only about 3% of them are stronger than $M_L = 3.0$.

The presence of quarry and mine blasts in the national catalogue prevents us to estimate its present-day completeness magnitude for the normal depth seismicity.
2. ANALYSIS OF STATION RELIABILITY

The performance of the individual stations is estimated by using as criterion the fraction of events that are localized with the station data (compared to the total number of events of the catalogue, which occurred during the time of station operation). Since the space distribution of the seismic events within the study area is strongly non-uniform, the location of the station site with respect to the shallow depth source zones is also taken into account in the evaluation of station effectiveness.

The analysis reveals that most of the new installed stations improved their performance after the first months of operation; also, several old stations show a noticeable increase of their reliability during the investigated period. For the stations exhibiting significant raise of their effectiveness, their highest recovery rates (of reliable data – P- and S-wave arrival times, used in seismic event localizations) have been taken into consideration.

![Image](image.png)

**Fig. 1** – The normal depth events localized during the study period; up – location of epicenters: grey dots – events with $1.2 \leq M_L < 3.0$, black dots – events with $3.0 \leq M_L < 4.0$, stars – events with $M_L \geq 4.0$; down – the histogram of event depths.
The results are presented below, in detail.

The location of the on-line stations equipped with velocity sensors, in operation at January 1, 2013, is shown in Fig. 3. Information on their installation date and present-day instruments is given in [9].

Fig. 2 – Histogram of event magnitudes: up – all events, down – events with $M_L \geq 3.0$.

Fig. 3 – The real time stations of the Romanian seismic network: white triangles – stations installed before January 1, 2008 (no upgrades during the period 2008–2013); black triangles – stations installed/ upgraded during the period 2008–2013; grey dots in the background – epicenters of normal depth events with local magnitude $\geq 1.2$. In the left upper corner – the stations in operation in Bucharest city (located within the thick line rectangle on the map).
For each station we display the fraction of events with local magnitude greater or equal to a specified value, that have been localized using the station records; to account for the prominent nonuniform space distribution of the seismic sources, the recovery rates of the events with epicentral distances less than 100 km, 200 km and 300 km, respectively, are displayed distinctly. It should be stressed that these recovery rates are not of the same statistical value, because the total number of events localized within the selected distance ranges differ considerably from station to station (from several tens to several hundreds).

2.1. THE STATIONS FROM WESTERN AND CENTRAL ROMANIA

The performance of the real time stations from Maramureș and Crișana, north-western Romania, is presented in Fig. 4.

![Graph showing seismic station performance](image)

Fig. 4 – The seismic stations from Maramureș and Crișana – the fraction of events with local magnitude greater or equal to a specified value that have been localized using the station records. The recovery rates of the events with epicentral distances less than 100 km, 200 km and 300 km, respectively, are displayed distinctly; the number of events within each epicentral distance range, that have been localized by using the station data, is given in brackets. The vertical thick line shows the magnitude of the weakest event localized with the station data. The diagrams are representative for the indicated time intervals (the time periods when the stations reached their highest performance).

The stations of Maramureș – CEI and BMR – show notably different reliabilities. Since its installation in 2011, CEI station has been used to the localization of no more than 3 shallow depth seismic events (all occurred during 2013); two of them are moderate-sized (ML = 4.0, and ML = 3.9, respectively), and have epicentral distances larger than 200 km (285 and 230 km, respectively), the
The performance of the stations of the Romanian seismic network

smallest one has local magnitude 2.7 and epicentral distance 160 km. We notice that during the time of station operation, no event larger than $M_L = 2.7$ has been localized within a radius of 100 km from the station; likewise, only 2 events with $M_L \geq 3.0$ ($M_L = 3.0$ and $M_L = 3.1$, respectively) have been localized within the epicentral distance range 100–200 km. On the other hand, BMR station – which reached the highest recovery rates in the period 2012–2013 – is reliable for the events with local magnitude $\geq 2.8$ which occur at epicentral distances less than 200 km (above 80% recovery rates), as well as for the events with $M_L \geq 2.8$ located at epicentral distances $< 300$ km (recovery rates greater than 60%); however, the station exhibits rather modest results for magnitudes below $M_L = 2.4$, even for the nearest sources.

Significantly higher effectiveness is attained by the stations of Crişana. DRGR achieved 90% recovery rate of the events with local magnitude greater or equal to 1.3 (the lowest magnitude in the catalogue) localized within a radius of 200 km from the station, and over 60% recovery rate of the events with $M_L \geq 1.3$ and epicentral distance $< 300$ km. SIRR is reliable for the weakest seismic sources from the catalogue, situated closer than 100 km (above 65% recovery rate of the events with $M_L \geq 1.6$, during the period 2010–2013), and also for the events with local magnitude greater or equal to 2.2, located at epicentral distances up to 200 km (recovery rates exceeding 60%).

The results of the on-line stations from Banat, south-western Romania, are shown in Fig. 5.

TIM and BANR stations are less effective, reliable for the close sources – distances $< 100$ km – only for magnitudes $M_L = 2.9$ and above (recovery rates higher than 69%). For the events with epicentral distances $< 200$ km, BANR is reliable for local magnitudes $\geq 3.0$ (recovery rates greater than 65%), while TIM only for magnitudes $\geq 3.3$ (recovery rates $> 60$%).

GZR, HERR, MDVR and BZS stations are all four effective for the near events, even for the lowest magnitudes of the catalogue (over 65% recovery rates of the sources with epicentral distances $< 100$ km). For the events located at distances $< 200$ km, MDVR and BZS stations are also reliable for the lowest magnitudes, while GZR and HERR reached recovery rates $> 60$% solely for local magnitudes 2.3 and larger. The best results are achieved by BZS: over 90% recovery rate of the events with $M_L \geq 1.5$ and epicentral distance $< 200$, and above 65% recovery rate of the sources with $M_L \geq 1.3$ located within a radius of 300 km.

The performance of the stations from Transilvania, central Romania, is shown in Fig. 6.

We note that SIBR and TNR stations are not considered in this analysis, due to the data transmission problem they were constantly faced with, during the study time interval [9].
Fig. 5 – The seismic stations from Banat. For details see the caption of Fig. 4.

The remaining stations from Transilvania exhibit also rather modest results. The less effective one is MDB, with recovery rates above 60% only for the sources with $M_L \geq 3.0$ located within a radius of 100 km from the station, and for the earthquakes with $M_L \geq 3.7$ occurred at epicentral distances up to 200 km.

DEV (during 2012–2013), CJR (during 2010–2013) and ARCR (during 2011–2013) are reliable for the events with $M_L = 2.7–2.8$ and stronger (over 60% recovery rates), in both epicentral distance ranges 0–100 km and 0–200 km. Likewise, OZUR station (during 2012–2013) is reliable for the near sources with local magnitude $\geq 2.6$, and for the events with $M_L \geq 2.7$, located at distances $< 200$ km.

Better results are displayed by DOPR station, but only for the close events – 61% recovery rate of the sources with $M_L \geq 2.4$ and epicentral distances less than 100 km – while for the sources located within a radius of 200 km its effectiveness
The performance of the stations of the Romanian seismic network is similar to that of DEV, CJR, ARCR and OZUR – recovery rate above 60% for the events with local magnitude ≥ 2.8.

On the contrary, JOSR station displays comparable results with DEV, CJR, ARCR and OZUR for the sources situated at distances < 100 km – 61% recovery rate of the events with $M_L \geq 2.7$, during 2012–2013 – but it is noticeably less effective in the distance range 0–200 km – above 60% recovery rates only for the events with $M_L \geq 3.1$.

2.2. THE STATIONS FROM SOUTHERN ROMANIA

Figure 7 presents the results of the real time stations from western Muntenia. We notice that the recently installed BAIL and COPA stations have not been used yet in the localization of any crustal event. Both stations are situated in zones
with low seismicity – no shallow event has been localized closer than 95 km from the stations, during their time of operation. Nevertheless, a moderate size crustal earthquake with local magnitude 4.0 occurred at 180 km from BAIL and 165 km from COPA; also a normal depth earthquake with $M_L = 3.6$ occurred at 120 km from BAIL.

The contribution of RMVG station is also very poor. Since its installation in 2009, RMVG has been used to the localization of only 3 shallow depth seismic sources: two events in 2010 ($M_L = 3.2$, at 95 km epicentral distance, and $M_L = 4.0$, at 55 km epicentral distance, respectively), and one event in 2011 ($M_L = 2.5$, at 95 km epicentral distance).

Among the remaining stations, VLAD, CRAR, ZIMR, RMGR and GOLR display also modest results. VLAD, ZIMR and CRAR stations are also placed in zones with low seismicity. No seismic event has been localized closer than 130 km from VLAD, during the time of station operation. Similarly, no event has been localized within a radius of 60 km from ZIMR, and only 2 weak events ($M_L = 2.5$ and $M_L = 2.4$, respectively) have been localized at epicentral distances smaller than 60 km from CRAR. In fact, both ZIMR and CRAR stations contributed to the localization of no more than 5 crustal seismic sources in the distance range 0–100 km. For epicentral distances up to 200 km, VLAD is effective for the events with $M_L = 3.0$ and stronger (recovery rates above 65% during 2013), while CRAR (during 2010–2013) and ZIMR are reliable only for magnitudes $M_L = 3.3$ and above (recovery rates slightly below 70%).

Due to their location in the vicinity of seismically active areas, RMGR and GOLR stations display considerably higher effectiveness than VLAD, ZIMR and CRAR, in the epicentral distance range 0–100: RMGR exhibits 67% recovery rate of the events with $M_L \geq 3.1$ (during 2008–2011), and GOLR shows 72% recovery rate of the sources with $M_L \geq 3.0$ (during 2012–2013). Nevertheless, in the distance range 0–200 km, the reliability of GOLR is comparable to that of ZIMR and CRAR stations – recovery rates above 60% for the events with local magnitude greater or equal to 3.2 – while the usefulness of RMGR is significantly lower, its reliability decreasing strongly for seismic sources with local magnitude below 3.7.

The stations PUNG, HUMR (during 2011–2013), MTUR and SRE (during 2010–2013) achieved similar performances in the localization of the normal depth events with epicentral distances less than 100 km. Recovery rates exceeding 60% are reached by PUNG and HUMR for the events with $M_L \geq 2.6$, and by SRE and MTUR for the events with $M_L \geq 2.7$; we note the rather high recovery rates – above 55% – displayed by MTUR for the weakest sources ($M_L$ between 1.4 and 2.6).
Fig. 7 – The seismic stations from western Muntenia. For details see the caption of Fig. 4.
By contrast, for the epicentral distance range 0–200 km the reliabilities of the four stations differ noticeably: HUMR, PUNG and MTUR exhibit 63% recovery rate of the events with $M_L \geq 2.7$, $M_L \geq 2.8$ and $M_L \geq 3.1$, respectively, while SRE shows 84% recovery rate of the sources with $M_L \geq 2.9$; below these magnitude thresholds the effectiveness of the four stations decreases rapidly.

The stations located in the mountain region exhibit the best results from western Muntenia. VOIR, ARR (during 2011–2013) and LOT (during 2011–2013) reached recovery rates higher than 90%, over 80% and above 60%, respectively, for the events with $M_L \geq 1.3$ (the entire magnitude range of the catalogue), which occurred at epicentral distances < 100 km. VOIR attained also high recovery rates (> 70%) for the sources with $M_L \geq 1.3$ located within a radius of 200 km. In the same epicentral distance range (0–200 km) LOT reached recovery rates exceeding 60% for the events with magnitude $\geq 2.5$, and ARR for the sources with $M_L \geq 2.6$.

The performance of the stations from eastern Muntenia is presented in Fig. 8. We notice that the 6 stations in operation in Bucharest city: BAPR, BSTR, BTMR, BUC, BVCR, INCR, which are only occasionally used in the localization of the weak-to-moderate seismic events, are not considered in this analysis [9].

We also notice the poor contribution of the recently installed BISRR station, which was used to the localization of only 3 weak, shallow depth events (magnitudes between 2.2 and 2.6, epicentral distances less than 65 km), but was
not considered in the localization of 2 seisms with $M_L \geq 4.0$ ($M_L 4.0$ and $M_L 4.3$, respectively) that occurred at epicentral distances of about 75 km, and of an earthquake with $M_L 3.6$, located at less than 30 km from it.

Several stations display also rather modest results. BUC1 (during 2011–2013), AMRR, PGOR, SECR (during 2010–2013) reached recovery rates above 60% only for the events with local magnitude greater or equal to 3.0, in both epicentral distance ranges 0–100 km and 0–200 km. PLAR (during 2012–2013), exhibits similar reliability for the sources located at distances < 100 km, but it is significantly less effective in the distance range 0–200 km – over 60% recovery rates only for the events with $M_L \geq 4.0$.

Significantly better results are achieved by SGRR (during 2012–2013), RASA, LEHL and ISR (during 2009–2013); they show recovery rates above 60% for the events with local magnitude greater or equal to 2.4–2.5, located within a radius of 100 km, as well as for the events with $M_L = 2.6–2.7$ and stronger, situated at epicentral distances up to 200 km.

The stations SULR (during 2011–2013) and GRER (during 2009–2013) exhibit slightly lower performances; they are reliable for the sources with $M_L \geq 2.6$, located at distances < 100 km, and for the events with magnitude greater or equal to 2.8 and 2.9, respectively, situated at epicentral distances < 200 km.

Among the stations of eastern Muntenia, the highest contribution to the monitoring of the normal depth seismic events is brought by MLR observatory. It attained about 80% recovery rate of the sources with $M_L \geq 1.3$ (the whole magnitude range of the catalogue), which occurred at epicentral distances up to 200 km, and over 50% recovery rate of the events with $M_L \geq 1.3$ localized at epicentral distances less than 300 km.

Figure 9 presents the stations from Dobrogea, south-eastern Romania.

We notice that CVD1 station, which has been installed in the neighbourhood of CVD in 2010, but is not currently used in the localization of the seismic events, is not considered in this analysis [9].

Among the remaining stations from Dobrogea, CVD exhibits the weakest results: recovery rates above 60% for the events with local magnitude greater or equal to 2.9, in the epicentral distance range 0–100 km, and for the sources with $M_L \geq 3.0$, in the distance range 0–200 km.

EFOR (during 2009–2013) and HARR (during 2009–2013) are more effective for the close events (epicentral distances up to 100 km), both stations reaching over 60% recovery rate of the sources with $M_L \geq 2.6$; in the distance range 0–200 km, however, the station performances differ considerably: HARR is reliable for the events with local magnitude greater or equal to 2.6, while EFOR only for the events with $M_L \geq 3.0$, similarly to CVD.
Fig. 8 – The seismic stations from eastern Muntenia. For details see the caption of Fig. 4.
The performance of the stations of the Romanian seismic network

Fig. 9 – The seismic stations from Dobrogea. For details see the caption of Fig. 4.
Better results are displayed by ICOR (during 2012–2013) and MANR (during 2010–2013), which are reliable for the sources with $M_L \geq 2.4$ located within a radius of 100 km, and for the events with local magnitude 2.7 and stronger, occurring at epicentral distances less than 200 km.

The usefulness of MFTR and TLCR is even higher, they display recovery rates above 60% for the events with magnitude larger or equal to 2.1 and 2.0, respectively, in the epicentral distance range 0–100 km, and for the sources with $M_L \geq 2.7$ and $M_L \geq 2.5$, respectively, in the distance range 0–200 km.

The best performances among the stations of Dobrogea are attained by CFR, TIRR and TLB. CFR and TIRR achieved recovery rates above 75% for the events with local magnitude greater or equal to 1.2 (the lowest magnitude in the catalogue) localized at epicentral distances < 200 km, and above 50% for the sources with $M_L \geq 1.2$ situated at distances up to 300 km. TLB attained 83% recovery rate of the events with magnitude greater or equal to 1.4 (the smallest magnitude of the catalogue, during the time of station operation) located within a radius of 100 km, and 65% recovery rate of the events with $M_L \geq 1.4$, which occurred at epicentral distances less than 200 km.

2.3. THE STATIONS FROM EASTERN ROMANIA

The results of the real time stations from Moldova, eastern Romania, are displayed in Fig. 10.

IAS, GIRR and GHRR are by far the less performing stations of the region.

IAS is situated in a low seismicity area; only 8 events have been localized closer than 60 km from the station site, during 2009–2013. In this period IAS contributed to the localization of no more than 8 events within a radius of 100 km. In the epicentral distance range 0–200 km, the station effectiveness is low as well – recovery rates greater than 60% only for the sources with $M_L \geq 3.3$.

Although GIRR is situated closer to the seismically active areas, and GHRR is placed in a seismic source zone, their usefulness is even lower: they reached recovery rates above 60% for the events with local magnitude greater or equal to 3.3 and 3.4, respectively, in the epicentral distance range 0–100 km, and for the events with $M_L \geq 3.5$, in the distance range 0–200 km.

The performance of PRAR is also rather modest: 79% recovery rate of the sources with $M_L \geq 2.9$, located at epicentral distances <100 km, and 65% recovery rate of the events with $M_L \geq 3.0$, which occur at distances less than 200 km. Below these magnitude thresholds the reliability of PRAR decreases considerably.

The stations TESR, PETR (during 2009–2013), ODBI (during 2011–2013) and BIR display significantly better results in the localization of the close shallow depth seismic sources (epicentral distances up to 100 km); recovery rates greater than 60% are attained by TESR for the events with local magnitude 2.5 and stronger, by PETR and ODBI for the events with $M_L \geq 2.6$, and by BIR for the events with $M_L \geq 2.7$. The reliabilities of the four stations differ to a larger extent in the epicentral distance range 0–200 km: recovery rates over 60% are reached by
BIR for the events with $M_L \geq 2.7$, by TESR for the events with $M_L \geq 2.8$, by PETR for the events with $M_L \geq 2.9$, while by ODBI only for the sources with $M_L \geq 3.1$.

Fig. 10 – The seismic stations from Moldova. For details see the caption of Fig. 4.
The most effective stations of eastern Romania are VRI and PLOR from Vrancea region, and BURAR and BIZ from northern Moldova. All four stations exhibit high recovery rates of the close sources (distances < 100 km), even for the lowest magnitudes of the catalogue: VRI and PLOR show recovery rates of 94% and 87%, respectively, for the events with $M_L \geq 1.3$, while BURAR and BIZ display recovery rates of 97% and 75%, respectively, for the events with $M_L \geq 1.8$. For epicentral distances up to 200 km, VRI is reliable for the seismic sources with $M_L \geq 1.9$, PLOR for the sources with $M_L \geq 2.1$, BURAR for the events with $M_L \geq 2.2$ and BIZ for the events with $M_L \geq 2.6$. We note that both VRI and BURAR stations exhibit over 60% recovery rate of the sources with $M_L \geq 2.6$, located within a radius of 300 km.

3. DISCUSSION

The presented results provide a measure of the overall network performance regarding the monitoring of the local normal depth seismic activity, and allows us to quantify the value of the individual stations for the localization of the crustal seismic events in the study area.

The analysis of station effectivity for the near sources – located at epicentral distances less than 100 km – points out several levels of station performance (Fig. 11). Most of the stations – about 2/3 of the total – are reliable for the events with local magnitude $\geq 2.7$ (recovery rates above 60%). It is worth mentioning that 17 stations – distributed in all regions – achieved high recovery rates for the entire magnitude range of the catalogue: DRGR and SIRR in Crisana, BZS, MDVR, HERR, GZR in Banat, MLR, VOIR, ARR, LOT in Muntenia, CFR, TIRR, TLB in Dobrogea, VRI, PLOR, BURAR, BIZ in Moldova. On the contrary, effectivity below the average is observed at several stations from Muntenia: GOLR, SECR, PLAR, PGOR, BUC1, AMRR, as well as at CVD in Dobrogea, PRAR in Moldova, MDB in Transylvania, BANR and TIM in Banat. The study points also out several stations with particularly low performances: CEI in Maramureş, BISRR, RMVG, CRAR, ZIMR, RMGR in Muntenia, GHRR, GIRR, IAS in Moldova, and two completely underperforming stations: BAIL and COPA in southern Muntenia.

Figure 12 illustrates the station usefulness for locating the events which occur at epicentral distances up to 200 km. Several performance levels are evidenced in this larger epicentral distance range as well. More than half of the stations are reliable for the events with local magnitude $\geq 2.7$, and over 3/4 of them are reliable for the events with $M_L \geq 3.0$. We notice that the stations DRGR, BZS, MDVR, VOIR, MLR, CFR, TIRR, TLB are effective for the entire magnitude range of the catalogue, 5 of them – DRGR, BZS, MLR, CFR, TIRR – achieving remarkably high recovery rates, greater than 78%. In contrast, notably
The performance of the stations of the Romanian seismic network

poor results are obtained by CEI station in Maramureș, MDB station in Transilvania, BISRR, RMVG, RMGR, PLAR in Muntenia, GHRR, GIRR in Moldova. As already mentioned, BAIL and COPA in southern Muntenia are totally unused stations.

The station performance evaluation summarized above supports the suitability of the present configuration of the national seismic network for the monitoring of the crustal seismicity on the territory of Romania. The distribution of the seismic stations and the quality of their records assure a proper seismic survey of the seismogenic zones located within the national borders.

The only still poorly instrumented source zone is Maramureș – an area where the historical information indicates the occurrence of several events with epicentral macroseismic intensity 7 (MSK scale), and maximum observed epicentral intensity 8 [7]. For the localization of the events of north-western Romania, it is worth mentioning the contribution of the on-line data provided by 3 seismic stations from abroad: KWP from Poland, PSZ and especially TRPA, both from Hungary (data are available as a result of the bilateral agreements of the National Institute for Earth Physics of Bucharest with the Institute of Geophysics of the Polish Academy of Sciences, Warsaw, and Kövesligethy Radó Seismological Observatory of the Hungarian Academy of Sciences, Budapest, respectively).

In contrast, we remark a rather high station density in south-western Romania, in a particularly low seismicity area. It should be stressed that the seismic activity in north-western Bulgaria is low as well, therefore the seismic monitoring in the region does not justify a large number of stations.

The evaluation of the station performance in monitoring the Vrancea intermediate depth earthquakes – carried out in the first part of this study [9] – together with the present analysis on station effectivity in localizing the crustal sources with epicentral distances < 300 km allow us to conclude on the station capability to provide reliable data for the seismic survey of the territory of Romania.

According to our effectiveness criteria, MLR and VOIR in Muntenia, VRI, PLOR and BURAR in Moldova, CFR and TIRR in Dobrogea, DRGR in Crișana, BZS and MDVR in Banat are the most valuable network stations.

At the opposite pole, CEI in Maramureș, MDB in Transilvania, and RMGR in Muntenia exhibit particularly poor performances, while BAIL, COPA, RMVG, BISRR in Muntenia, GHRR and GIRR in Moldova are completely underperforming stations.

The conclusions of our two-part study provide essential information for decisions regarding the future development of the national seismic network.
Fig. 11 – The network station reliability for localizing the seismic events which occur within the epicentral distance range 0–100 km.

To increase the overall network effectiveness, the shutdown or relocation of the most underperforming stations should necessarily be taken into consideration. BAIL and COPA are located in a low-seismicity area with a dense station distribution, while RMVG, BISRR, GHRR and GIRR operate in the vicinity of significantly more reliable stations (less than 50 km apart). We should mention that BAIL and COPA, as well as PUNG and VLAD, have been installed in south-western Romania in the framework of the project “Danube Cross-border System for Earthquakes Alert” (a part of the Romania-Bulgaria Cross Border Cooperation Program 2007–2013); the last two stations reached an average performance level in localizing the seismic events, in strong contrast with BAIL and COPA.

On the other hand, the seismic stations are sparse in north-western Romania; moreover, the weak effectivity of CEI results in a poor monitoring of the Maramureș seismogenic region.

Similarly, the northern and eastern Moldova are poorly instrumented; IAS is a station with low performances and the results of PRAR are modest as well. We
should mention that, for the localization of the events of north-eastern Romania, the real time data provided by 4 stations – LEOM, MILM, KISS and SORM – operating in the Republic of Moldova (stations installed by the National Institute for Earth Physics of Bucharest, in cooperation with the Kishinev Institute of Geophysics and Seismology) have been used as well.

A single, low-performing station – MDB – is operating at present in the weak seismicity zone of central Romania; the area is, nevertheless, satisfactorily covered, due to the contribution of the surrounding good performance stations.

The siting of new stations in northern Romania, in order to enhance the seismic survey of this part of the country, and the effectiveness raise of CEI and MDB stations (by appropriate strategies – upgrade of instruments, relocation of sensors) are next important steps towards an optimal earthquake monitoring of the territory of Romania.
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