Processing and analysis of seismicity in Provadiya region in 3 year period

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Обработка и анализ на сеизмичността в района на Провадия за три годишен период
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Абстракт
Районът на гр. Провадия се характеризира с ниска сеизмичност, като от началото на миналия век до 1980г. са се реализирали заметресения с манитуд не по-голям от 4.9. В близост до града се намира Мировското солно тяло, което е в експлоатация от 1956г. През последните 25г. броят на локалните земетресения значително нарастна. Наблюдаването на сеизмичността в региона се извършва от Локална сеизмологична мрежа от четири постоянни и 2 временни станции, всички оборудвани със съвременна широколентова цифрова апаратура. Сеизмичните сигнали от постоянните станции се предават в реално време към Националния сеизмологичен център в Националния институт по геофизика, геодезия и география, където се обработват от автоматичната обработваща система заедно със сигналите от останалите станции на Националната цифрова сеизмологична мрежа. За по-прецизно локализиране и интерпретиране, събитията в Провадийския регион се обработват интерактивно като се добавя и сеизмична информация от двете временни станции и се използва локален скоростен модел на разпространение на сеизмичните вълни. При обработката се прилага критерий за надеждно разпознаване на локалните заметресения от взривовете, голям брой от които се провеждат в неизвестни кариери. За периода октомври 2006г. до април 2009г. в 25км регион около гр. Провадия са локализирани 393 сеизмични събития, от които 205 са взривове, 184 са земетресения и 4 са неидентифицирани. Слаба сеизмичност се наблюдава по изявени и известни разломни структури в региона. Значително по-голям брой земетресения (96) са се реализирали в рамките на солното тяло и на 1 км от него в юго-западна посока. Магнитудът на земетресенията варира от 1.2 до 3.1. Най-силни са земетресенията от 05.11.2008г. с магнитуд ML=3.9 и от 07.10.2010г. с магнитуд ML=4.2, попадащи в границите на солния щок. Дълбочината на земетресенията достига до 5км. Подходящата конфигурация на мрежата, добавянето на временни станции и прилагането на новия скоростен модел повишава точността на определяне на параметрите на земетресенията. За да се даде по-пълна количествена оценка на характеристиките на сеизмичния режим в региона, да се определят сеизмично активните тектонски структури и да се даде отговор на въпроса за произхода на регистрираните събития – тектонски или техногенен, е необходимо да се натрупат данни за по-продължителен период от време.

Introduction

The town of Provadiya is located in seismically quite part of Bulgaria. There are no historical evidences for strong earthquakes in this region. In 1900 and 1902 two earthquakes of magnitude 4.1 and 4.9 were felt in the area. From 1902 to 1980 no strong or moderate earthquakes (ML > 3.5) are reported in the region (Grigorova et al., 1979). Mirovo salt deposit is situated near Provadiya and it has been in exploitation since 1956. The extraction of the salt from the dome is done by leaching method. In the last 25 years large number of small to moderate earthquakes (with magnitude M≤4.5) occurred near Provadiya and worried the local community. Generation of these earthquakes could be associated with activation of the complex geological structure and tectonic activity along the preexisting faults in the region, or/and it might be a consequence of the exploitation of the salt deposit. To monitor the seismicity in the region a local seismological network (LSN) was deployed in 1993. This network considerably increases possibilities for localization of the earthquakes in the region. To improve the accuracy of the earthquake hypocenter location (geographic coordinates and depth) and to increase the capacity of the network to detect small (lower than ML=1) magnitude earthquakes the LSN was modernized in 2006. The stations of the network are equipped with digital acquisition systems, 3 component geophones and modern radio connections (Dimitrova et al., 2006). The improvement of the location accuracy of the earthquakes is the key-factor for determining the nature of the observed seismicity in the Provadiya region.

Data processing

The LSN consists of four permanent seismic stations (PSS) (Provadiya – PRD, Nefsha – NEF, Avren – AVR and Roiak – ROIA) and two temporary stations (TSS) (Bozvelijsko – BOZ installed in 2006 and Dobrina – DOB installed it 2009) which are working as stand-alone points of observations. Data from PSS are transmuting in real-time mode to the National Data Centre (NDC) in National Institute of Geophysics, Geodesy and Geography (NIGGG) where these data are included in automatic data processing carried on by Seismic Network Data Processing Software (SNDP) (Haikin and Kushnir, 2005). To improve the accuracy of the earthquake hypocenter locations in the region around the salt dome, a specific velocity model was developed (Report, 2007) and was used in interactive data processing. To increase the capability of the network to detect lower magnitude earthquakes, data from TSS BOZ and DOB are added in the interactive processing. Table 1 represents the new velocity model used for hypocenter estimation of local events.

Table 1 The velocity model used in interactive data processing of local events

N layers	Vp (km/s)	Dept (km)
1	4.88	5
2	5.57	10
3	6.49	20
4	7.8	Half-space

Recorded seismic events are both tectonic events and quarry blasts. The quarry blasts are mostly carried out in unknown to us locations except quarry "Liuliak". A special criterion (Report, 2007) is applied to the data to discriminate earthquakes from blasts before analysing the seismicity pattern. This criterion comprises of:

- specific waveform shape – intensive surface wave in blasts' waveforms;
- specific spectrum of the blasts recorded by seismic stations PRD and NEF.

Gitterman and van Eck (1993) spectral method is applied for seismic records analysis. It is based on the presumption of interference phenomenon of seismic waves from multiple sources such as ripple-fired quarry blasts. As a result minima and maxima in the seismogram spectra of the quarry blats are observed. The values of these minima and maxima depend on the parameters of the blasts – number of blast series and delay between the series

This method can be applied at short epicentral distance (less than 20km) when the separation of seismic phases is difficult and the spectra of the whole signal are calculated instead of the individual phase's spectra.

Analysis of the seismicity in Provadiya region for the time period 01.10.2006 to 30.04.2009

393 seismic events have been localized in the 25km region around the town of Provadiya for the analyzed period. Appling the discrimination 205 of all events are classified as blasts, 184 are earthquakes and 4 events are undefined ones. Fig.1 represents the tectonic scheme of the region and location of all analyzed events. Green stars represent the blasts conducted in the quarry "Liuliak" (marked by yellow star) as well as in other quarries situated to the south of Provadiya and the salt dome (marked with blue diamond). The ML magnitude of the man-made events is between 1 and 2, and in some cases it reaches ML=2.6. Such strong blasts can influence the salt body and activate tectonic processes in the region. The earthquake epicenters are mapped with orange circles on the Fig.1. Weak seismicity is observed along known faults in the region. The largest number of earthquakes (96) is clustered in close proximity and within the salt dome. The earthquake epicenters located in vicinity (about 5km radius) of the salt dome are plotted on a geologic map with faults structures (Fig. 2). The black curve presents the contour of 2000m isodepth of the salt body. The earthquakes are distributed in southern and western direction from the salt dome and some of events occur within the salt body. The predominant depth of the earthquakes is from 1 to 2.5 km and reaches 5 km. The most magnitude estimates vary from 1.5 to 2.1 but some earthquakes have magnitude up to 3.1. A stronger earthquake of magnitude ML=3.9 occurred on November 5, 2008 and two years later, on October 7, 2010, other earthquake of greater magnitude ML=4.2 occurred. Epicenters of both earthquakes are located within the salt dome to the north. The epicenters of these earthquakes are shown with green and blue star respectively in Fig. 2.

The application of the new velocity model (Report, 2007) in the hypocentral determination improved the localization accuracy to +/-0.4 km in the network centre. The results obtained show that configuration of LSN Provadiya together with two TSS Bozvelijsko and Dobrina allow registration and localization of weak local earthquakes with ML<1 as well as reliable recording of the stronger earthquakes within and near the salt dome.

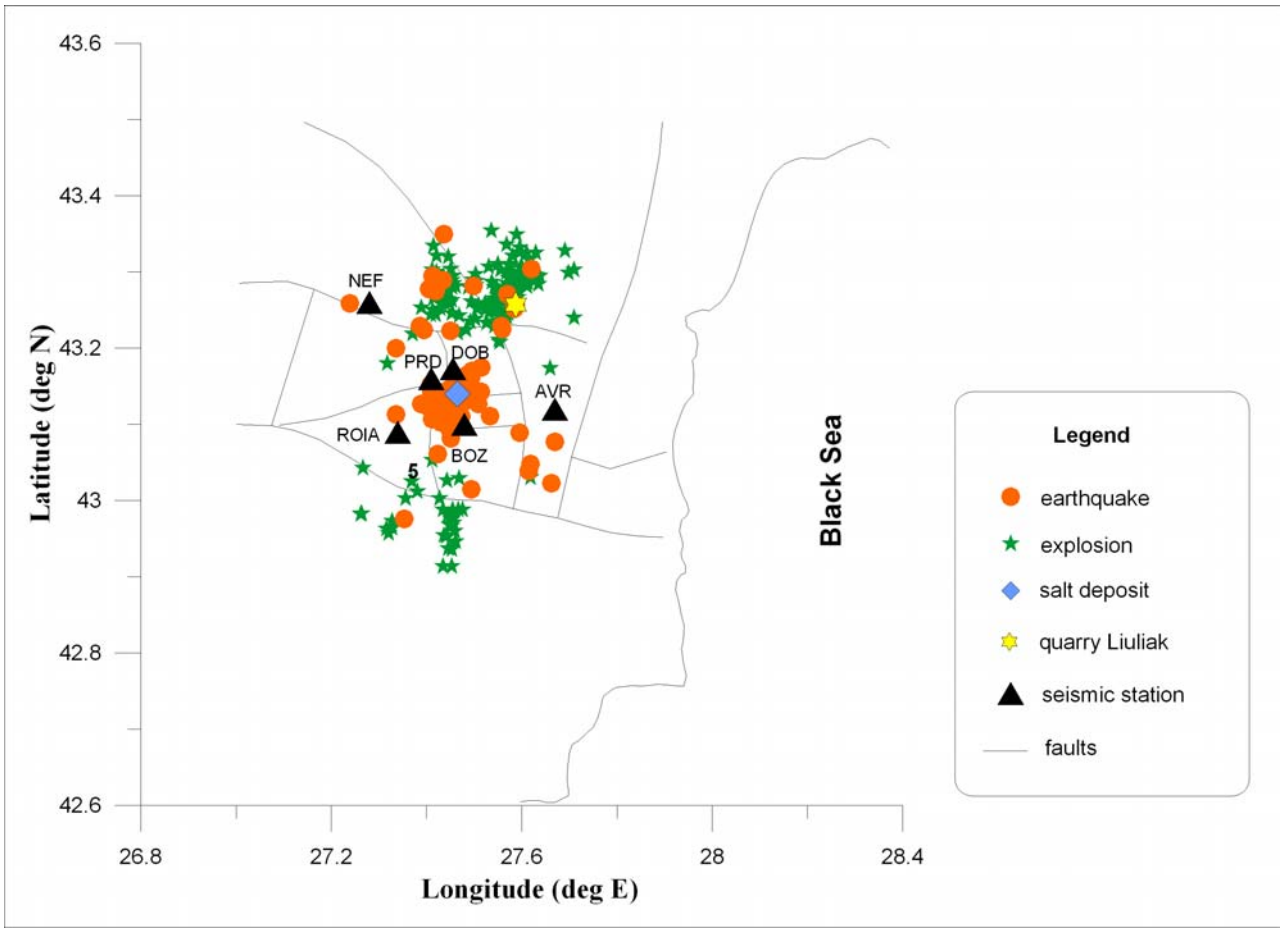


Fig 1 Seismic events occurred in the 25km region around Provadiya for period from 10/2006 to 04/2009 mapped on a tectonic scheme (according to Bokov and Chemberski, 1987 and Georgiev et al., 1985)

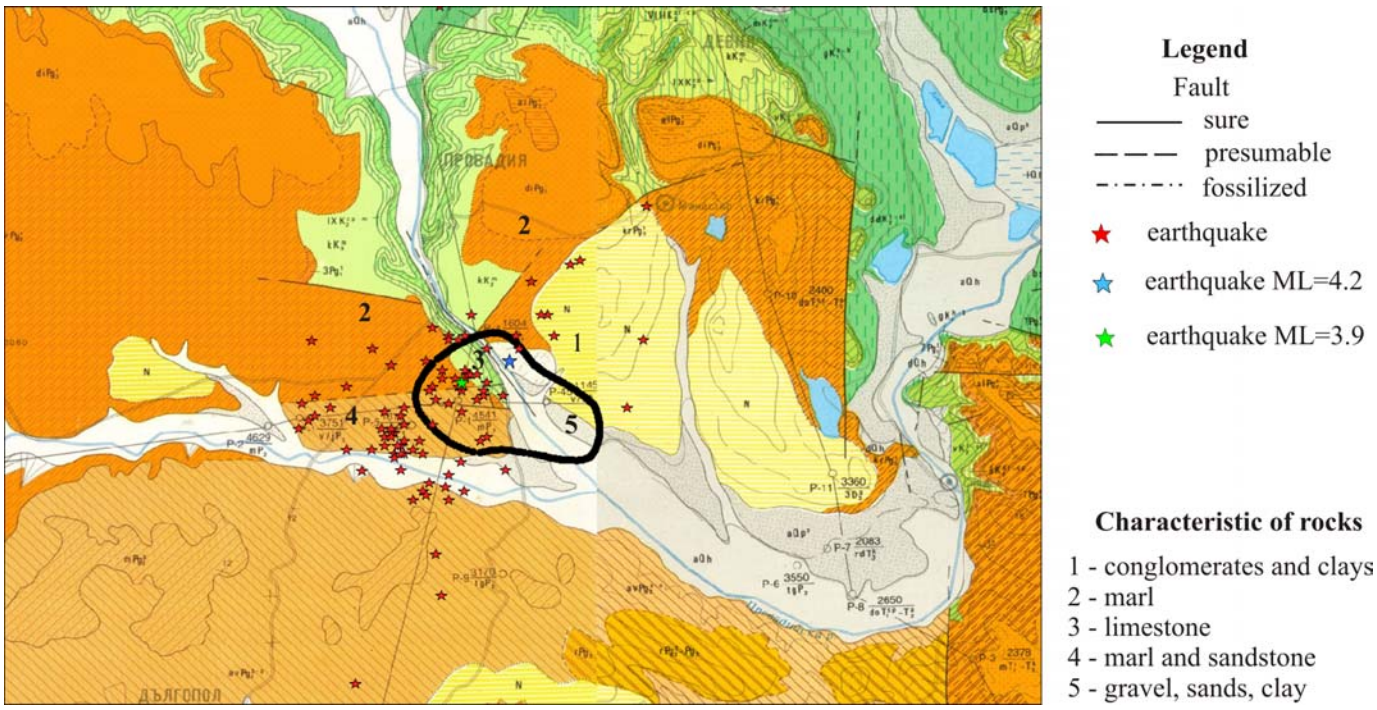


Fig 2 Epicenters of the earthquakes in the vicinity of the salt dome for the period 10/2006 to 04/2009, plotted on a geological map (according to Cheshitev et al., 1994). Black curve represents the 2000m isodepth of the salt body

Including TSS DOB in the interactive data processing, the accuracy of the depth estimation is improved. It is higher than in the horizontal direction and it reaches +/-0.3km.

We observed some changes in the number of the events during the analyzed period. Twice a sequence of four events was detected in the local zone. The first event is the strongest and it is followed by weaker events that can be considered as normal mainshock-aftershock sequence for microearthquakes. This might be linked to the leaching process. The existence of the active tectonic faults in the region and the contrast boundary between the salt dome and the surrounding structures is a precondition for the higher that presently observed seismic activity in the region.

Conclusions

The detailed study of the seismicity within three year period proved that the employed equipment ensures completely the purpose and aims of the network – monitoring the low magnitude seismicity in the region and improving the detection capabilities of the local network. The local digital network enabled implementation of modern methods of seismological analysis and led to improvement of the earthquake hypocentral localization and reliable screening of the quarry blasts. The natural seismicity within the studied region is concentrated in the south-western part of the Provadiyan salt dome, and most probably it is related to a re-activated tectonic fault near the dome. It is necessary to monitor the long-term seismicity in the Provadiya region for a statistical evaluation of the seismic regime in the region, for delineation the seismogenic tectonic structures and identification of the origin of the seismicity (induced or tectonic) in the Mirovo salt deposit.

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