Tectonic and induced seismicity in the region of Mirovo salt deposit, NE Bulgaria

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Introduction

The Mirovo salt deposit is situated in NE part of Bulgaria close to town of Provadiya (Figs. 1, 2). It has been in exploitation since 1956 using leaching technology. As a result a system of chambers – pillars is formatted within the salt body. The region is characterized with complex geological structure and several active or potential active faults .

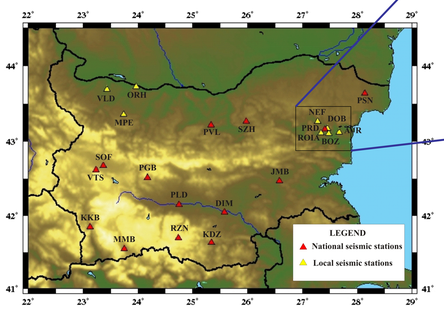

Fig. 1 Bulgarian Seismological Network

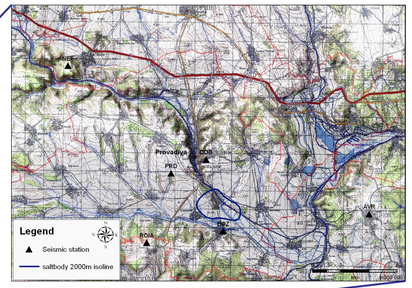

Fig.2 Local Seismological Network around Salt body

Since 1980 several moderate earthquakes (M>4.0) occurred in this region and worried the local community. For monitoring of the regional seismicity a Local Seismological Network (LSN) was deployed in 1993 around the salt deposit (Fig. 1, 2). To improve the accuracy of the earthquake hypocenter location a specific velocity model was developed and used in the data processing. The improvement of the location accuracy of the earthquakes is the key-factor for determining the nature of the observed seismicity.

Analysis of seismic activity

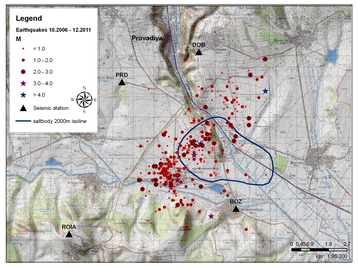

Fig. 3 Epicenters of the earthquakes in the region of the salt deposit

A number of 294 earthquakes are localized for the period from October, 2006 to December, 2011 (Fig. 3) within 5 km region around the salt body. The blue curve presents the contour of 2000m isodepth of the salt body. The earthquakes are distributed in south-western and north-eastern direction and several events occur within the north-western part of the salt dome.
The most part of magnitude estimates varies from 0.3 to 2.3 but some earthquakes have magnitude up to 3 (Fig. 4, Fig. 5). The distribution of the magnitude versus the studied time period from October, 2006 to December, 2011 is presented on the figure 4 and figure 5.

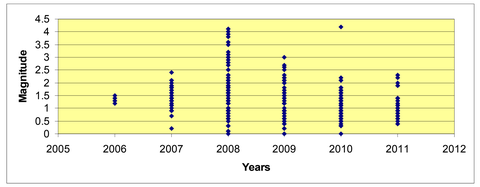

Fig. 4 Magnitude estimations versus the studied time period

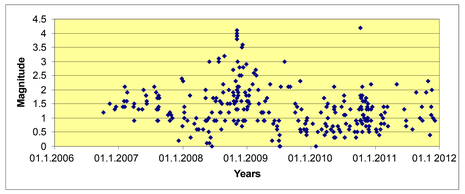

Fig. 5 Distribution of the magnitude estimations versus the studied time period

Two years later, on October 10, 2010, a moderate earthquake with ML=4.2 is realized several kilometers far from the salt body in north-eastern direction (the blue star on Fig. 3). After the event a number of small earthquakes (ML<2) is realized in the region (Fig. 5).

A stronger earthquake of magnitude ML=4.1 occurred on November 5, 2008. Epicenter of the earthquake is located within the salt dome to the north (the blue star on Fig.3). Several earthquakes with magnitude larger than 2.6 are realized before and after the main shock within 2008 year. This can be normal foreshock-aftershock sequence and typical behavior of induced events in the region.

On the figure 6 the distribution of the hypocenters versus the studied time period is presented. The earthquakes occur in upper part of the crust. The predominant depth of the earthquakes is from 1 to 2.5 km and reaches 5 km. It is seen that the whole 5km layer in depth is active.

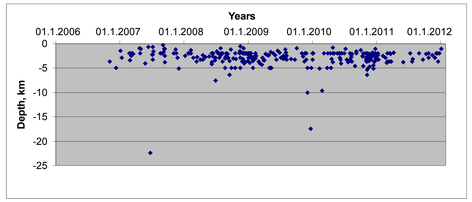

Fig. 6 Distribution of the hypocenters

Relocalization of the events in the region of the Mirovo salt dome

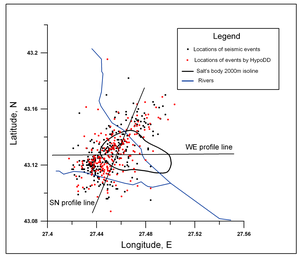

Fig. 7 Epicenters of the earthquakes in the region of Mirovo salt deposit determined by HypoDD and DHypo procedures

To improve the hypocenter estimations we applied the program package HypoDD over 227 events well clustered around the salt body. The program uses double difference algorithm to relocate the earthquakes. The relocation is two step process. The analysis of the phase data catalog to derive travel time differences for pairs of earthquakes is involved in the first step. In the second step, the travel time differences are used to determine double-difference hypocenter locations. On the figure 7 the epicenters of the earthquakes in close vicinity of the Mirovo salt dome are shown. The event locations are determined by DHypo (black dots) and HypoDD (red dots) programs.
As it is seen there is a weak migration of the hypocenters to the north-eastern direction.

Some of the earthquakes migrate closer to exploitation area and along the isoline 2000 m of the salt dome. Figure 8 and figure 9 present the relocated hypocenters (red dots) in SN and WE planes. Again we observe the migration of the relocated hypocenters in NE direction in depth.

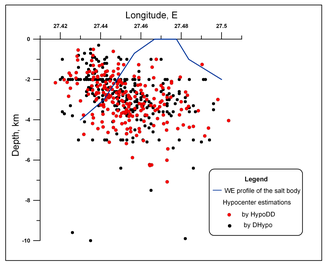

Fig. 8 Distribution of the hypocenters in WE plane

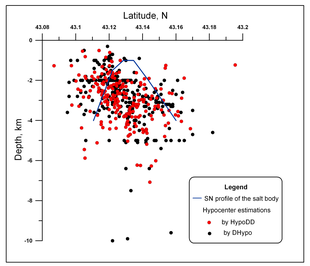

Fig. 9 Distribution of the hypocenters in SN plane

CONCLUSIONS

Deploying of Local Digital Seismological Network around the Mirovo salt dome enables monitoring of weak (M<1) and stronger local earthquakes and applying modern methods for data processing which improve accuracy of the hypocentral estimations. Current observations show predominant concentration of the seismic activity in close vicinity to the salt dome in south-western and north-eastern direction and some earthquakes occur within the deposit. Generation of these earthquakes could be associated with tectonic activity along the preexisting faults in the region, or/and it might be a consequence of the exploitation of the salt deposit. To clarify and separate the type of seismic events in the studied region it is necessary to continue the monitoring and analyzing the seismicity in the Mirovo salt deposit region long term.

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