

Deformatins and seismicity in the region of Mirovo salt deposit, Bulgaria

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Abstract:

Some results from the geodetic and seismological monitoring of a part of North-Eastern Bulgaria are presented. To evaluate the deformations in the region of Mirovo salt deposit we apply the precise method of permanent survey of displacements using GPS technology. The results of this monitoring show the velocity of displacement for the last 3 years of 6 permanent GPS stations confirming that the seismicity in Provadia region can be considered as “inductive seismicity” related to the intensive exploitation of Mirovo salt deposit. Generally, recent crustal motions in North-Eastern Bulgaria obtained by GPS data analysis reveal identical and no significant residual horizontal velocities relative to Eurasia. Only one point (st.Provadia) located in the central part of the region of interest shows a realtevely higher velocity (especially the vertical velocity) for the last years.

The region of Provadia city (North East Bulgaria) and Mirkovo salt deposit zone are characterized with prominent for Bulgaria seismicity – tectonic and probably induced (Fig. 1). The questions for the technogenic (anthropogenic) seismicity for the territory of the country and in particular for the region of Provadia are still under discussion. In close proximity of Provadia city, on 4 km South East – Mirkovo salt deposit is located, which is in exploitation since 1956. In the zone of that salt deposit since the beginning of last century to 1980 earthquakes with magnitude greater than 4,9 have been realized. During last 30 years the number of local earthquakes significantly increases as the strongest earthquake is with magnitude $M=4.4$ in 2004.

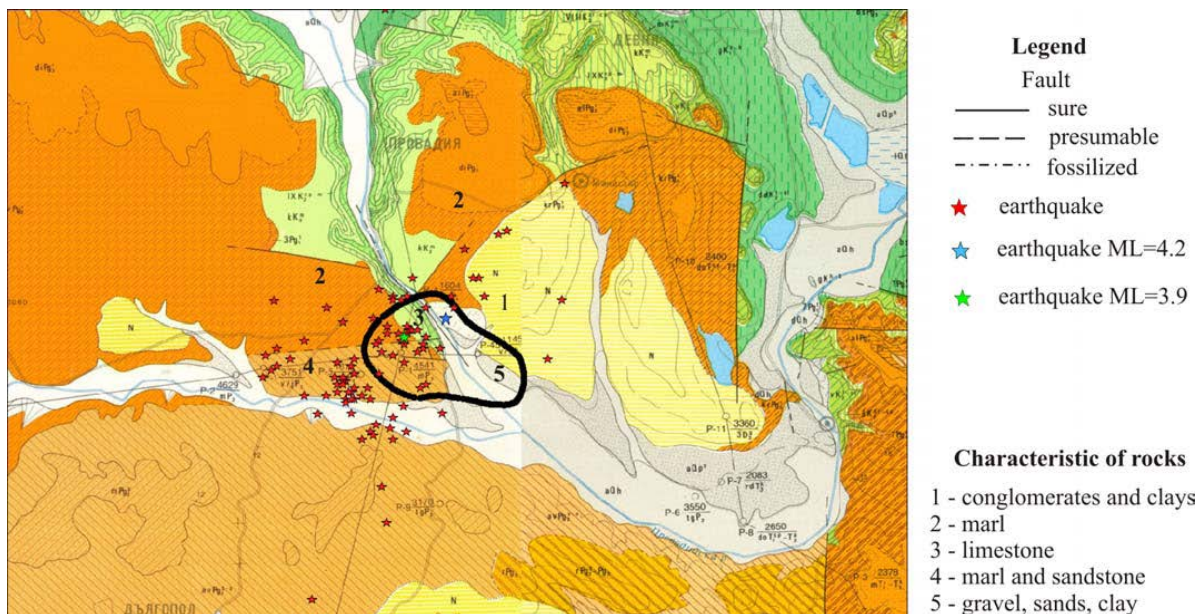


Fig. 1. Epicenters of the weak earthquakes after 2006 related to the geology map 1:100 000 (Cheshitev et al.,1999). The black line delimited the salt deposit body at 2000 m depth level

The monitoring on the seismicity in the region is performed from the Local seismological network of four constant and two temporary stations, all equipped with modern broadband digital sensors and acquisition systems. For the period after 2006 in 25 km area around Provadia city were localized 393 seismological events from which 205 are explosions, 184 are earthquakes and 4 are unidentified. Weak seismicity is observed on well-expressed and well-known fault structures in the region. Significantly bigger number of earthquakes were realized in the region of the salt body and in 1 km distance from it in South West direction. The magnitude of the earthquakes varied reaches up to 3.1 as the depth of the earthquakes reaches 5 km. The strongest earthquakes are those realized on 05.11.2008 with magnitude of $ML=3.9$ and on 07.10.2008 with magnitude $ML=4.2$ being within the borders of the salt typhon (Dimitrova et al., 2010).

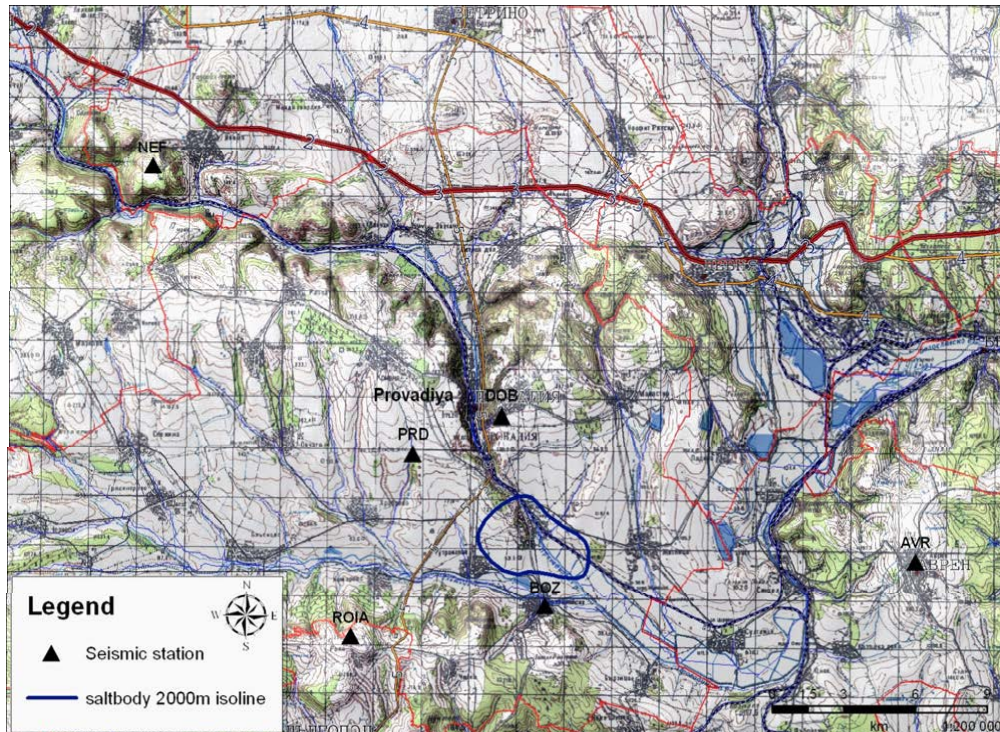


Fig. 2. Seismic stations of Local Seismological Network.

For geological monitoring of the deformations in the region of the Mirkovo salt deposit is applied most precise and contemporary method for permanent monitoring of movements using GPS technology.

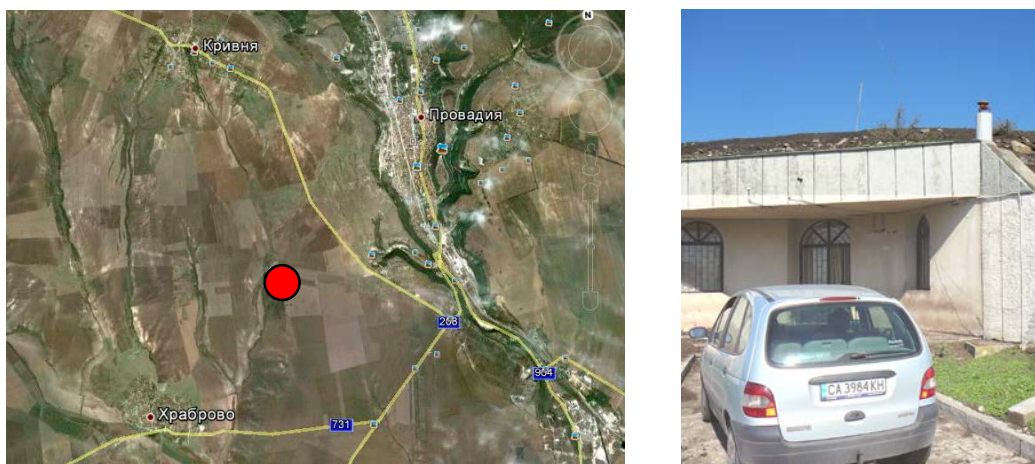


Fig. 3. Location of permanent GPS station in Izmatets region, materialized with observation pillar with facility for forced centring

The results from the observations of the permanent GPS station PROV in Provadia region are presented with time series from the coordinates of the station obtained by means of GAMIT/GLOBK software (fig. 3 and Table 1). Registrations of GPS station in Provadia city and near in radius of 50 kms permanent stations in Varna, Shoumenn, Shkorpilovtsi, Aitos and Dobrich, with their relative in comparison with stable Eurasia'2005 speed of time series from coordinates ETRS89 are presented in next Table and on Fig. 3. The results of the permanent geodesic monitoring showed almost identical in dimension speed of motion of the permanent GPS stations.

Provadia station is the only exception which shows speed on 1.9 ± 0.5 mm/year in South West direction and significant submerging with speed of -7.9 ± 1.6 mm/year. Seasonal movements are observed being registered during more than the 3 years permanent measurements. On the basis of these observations conclusion might be drawn that probably the observed seismicity in the Rprovadia region is induced seismicity resulting from intense exploitation of salt mining in the nearby (3-4 km) Mirovo salt deposit.

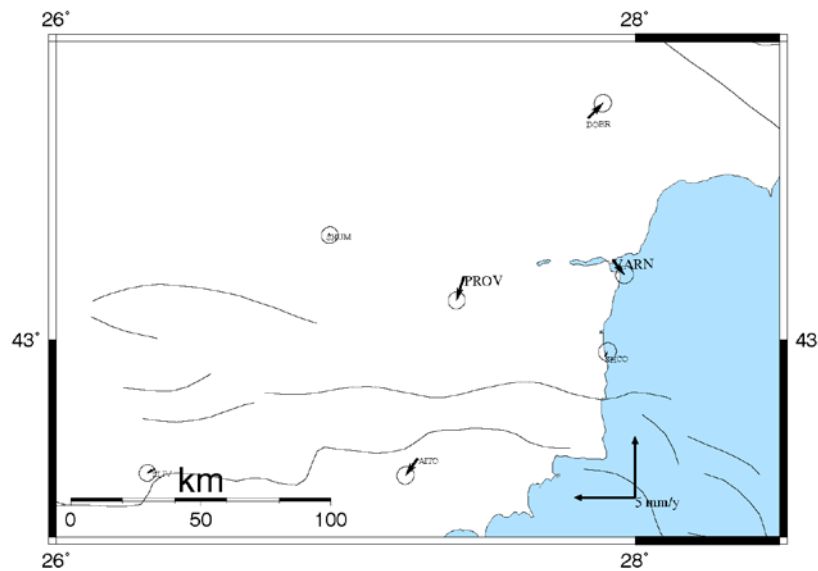


Fig. 3. The relative in comparison with the stable Eurasia'2005 speed form the time series of the coordinates ETRS89 of the permanent GPS stations in the region locate din radius of 50 km around Provadia city

Permanent GPS Station	North component Северна компонента N (mm/year)	East component E (mm/year)	Vertical component Up (mm/year)	Location
PROV	-1.9 ± 0.5	-0.6 ± 0.5	-7.9 ± 1.6	Provadia
VARN	-1.2 ± 0.5	1.0 ± 0.5	-2.5 ± 1.6	Varna
SHUM	-0.2 ± 0.4	0.0 ± 0.5	-2.6 ± 1.6	Shoumen
SHCO	0.4 ± 0.5	0.2 ± 0.5	-2.1 ± 1.5	Shkorpilovtsi
AITO	-1.4 ± 0.5	-1.0 ± 0.5	-1.3 ± 1.5	Aitos
DOBR	1.2 ± 0.5	1.2 ± 0.5	-1.4 ± 1.6	Dobrich

Table 1. Values of the relative speed in some GPS permanent stations (by components)

For evaluation of the natural and technogenic risks in the Mirkovo salt deposit are analyzed as well data from details geodesic monitoring of network of periodical (each year) precise measurements in the zone of Mirkovo salt deposit, as the network is created in the 90s. Re-measured are longitudes between 18 points (fig. 4) by laser telemeter of the Mekometer ME5000 firm which guaranteed accuracy of the measured distances of the order of (0,2mm + 0,2ppm) and with periodical GPS measurements. Comparing the distances shows the relative movement between the location points which are situated in close proximity to and above the salt body. Thus for example points 4 and 11 have been got nearer to one another for the time of one year with 94.1 mm, points 4 and 10 – with 83.4 mm, points 11 and 8 – with 49.7 mm.

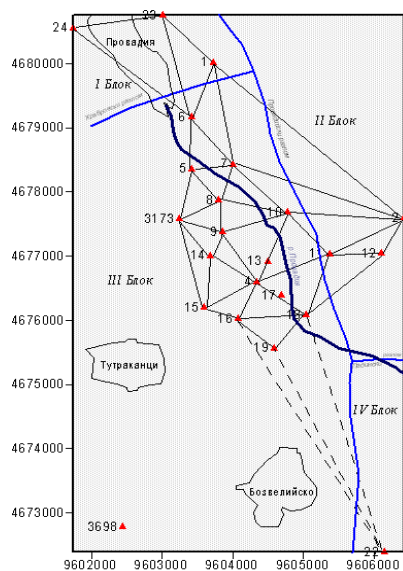


Fig.4 The detailed geodesic monitoring network in the region of the salt deposit re-measured each year with the high-precision methods (Geoprecis Ltd)

Conclusion:

The results from the geodesic monitoring of the deformation in the Mirkovo salt deposit region allow for the conclusion to be made that in and above the exploitation area of the salt deposit take place significant local deformations of the earth surface. These deformation processes could be explained with concentration of the epicenters of different in strength earthquakes in the region. The question stays open whether local movements and the induced anthropogenic regional seismicity to lead to activation of seismogenic faults which could lead to earthquake with $M > 6$. For clarifying this issue is needed new profound and complex research.

References:

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