The 2012 M_w5.6 earthquake in Sofia seismogenic zone – is it a slow earthquake

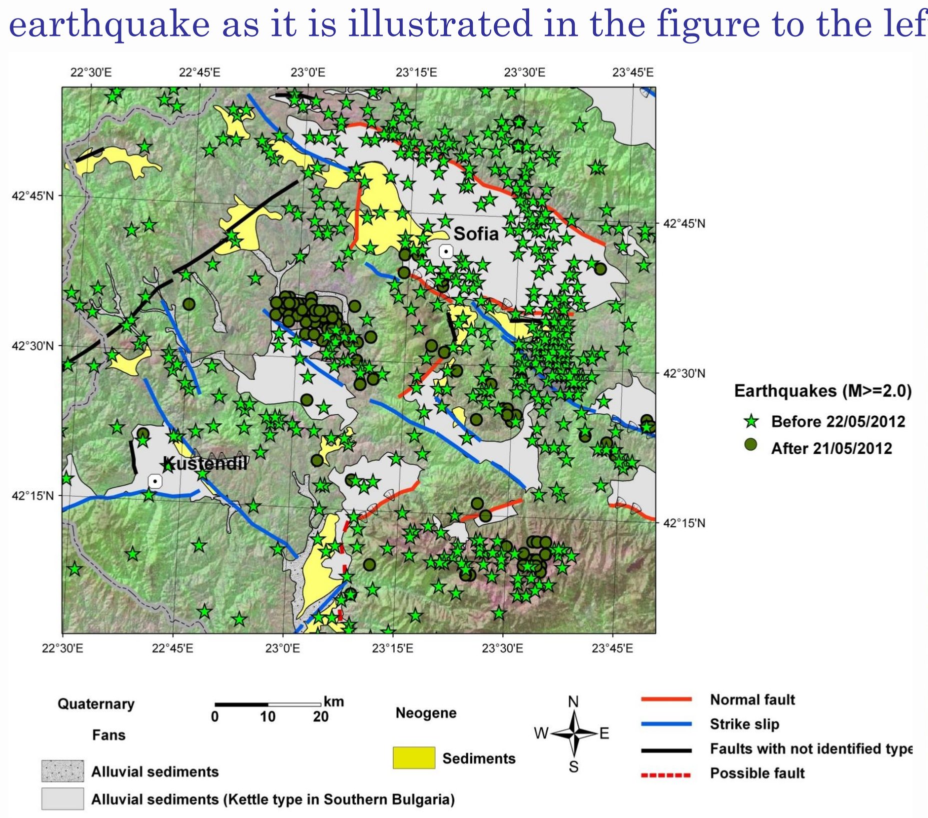
Raykova, P.[1], D. Solakov[1], K. Slavcheva[2], S. Simeonova[1], I. Aleksandrova[1]

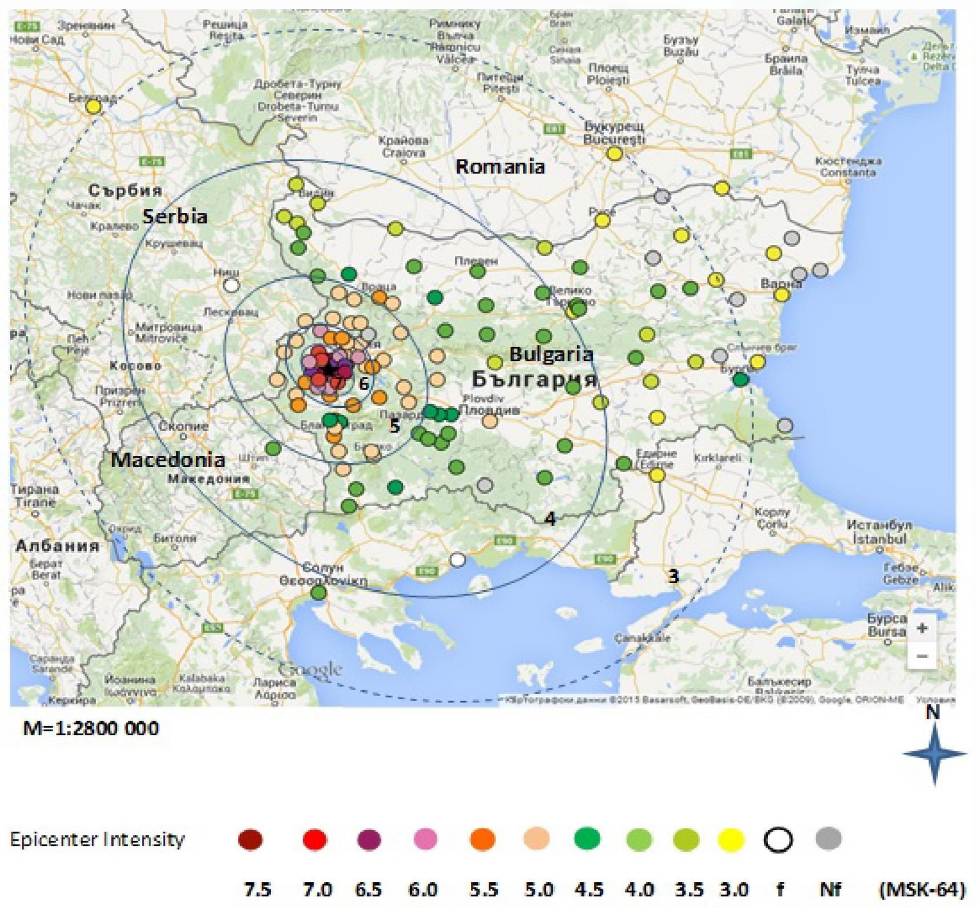
[1] – National Institute of Geophysics, Geodesy and Geography – BAS, Sofia, Bulgaria

[2] – NPP Kozloduy, Bulgaria

Recently (at the end of 20th century), the understanding of tectonic faulting has been shaken by the discoveries of seismic tremor, low frequency earthquakes, slow slip events, and other models of fault slip. These phenomena represent models of faulting that were thought to be non-existent and theoretically impossible only a few years ago. Slow earthquakes are seismic phenomena in which the rupture of geological faults in the earth's crust occurs gradually without creating strong tremors. Despite the growing number of observations of slow earthquakes their origin remains unresolved.

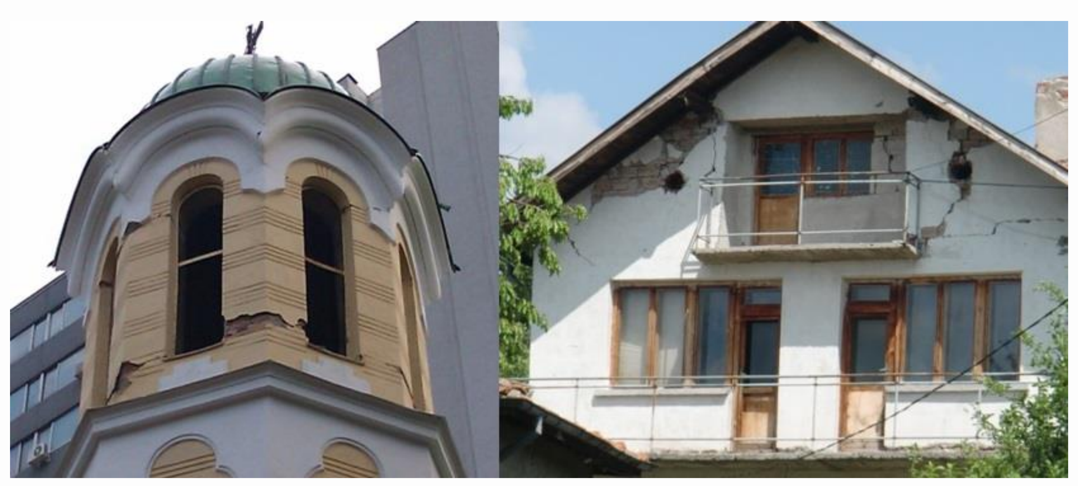
The Sofia area is the most populated, industrial and cultural region of Bulgaria that faces considerable earthquake risk. The Sofia seismogenic zone is located in South-western Bulgaria – the area with pronounce tectonic activity and proved crustal movement. It is worth mentioning that the 2012 earthquake occurred in the area characterized by a quiescence (of 26 years) for small to moderate earthquake as it is illustrated in the figure to the left.





The present study focuses on the characteristics of the M_w5.6 intraplate earthquake occurred in Sofia zone on May 22nd, 2012, after a quiescence of 95 years for moderate events.

The M_w5.6 earthquake was largely felt on the territory of Bulgaria and the neighbouring countries: northern Greece, eastern Serbia and FYROM, and southern Romania. No casualties and severe injuries were reported. Mostly small to moderate damages were observed in the cities of Pernik and Sofia and their surroundings.



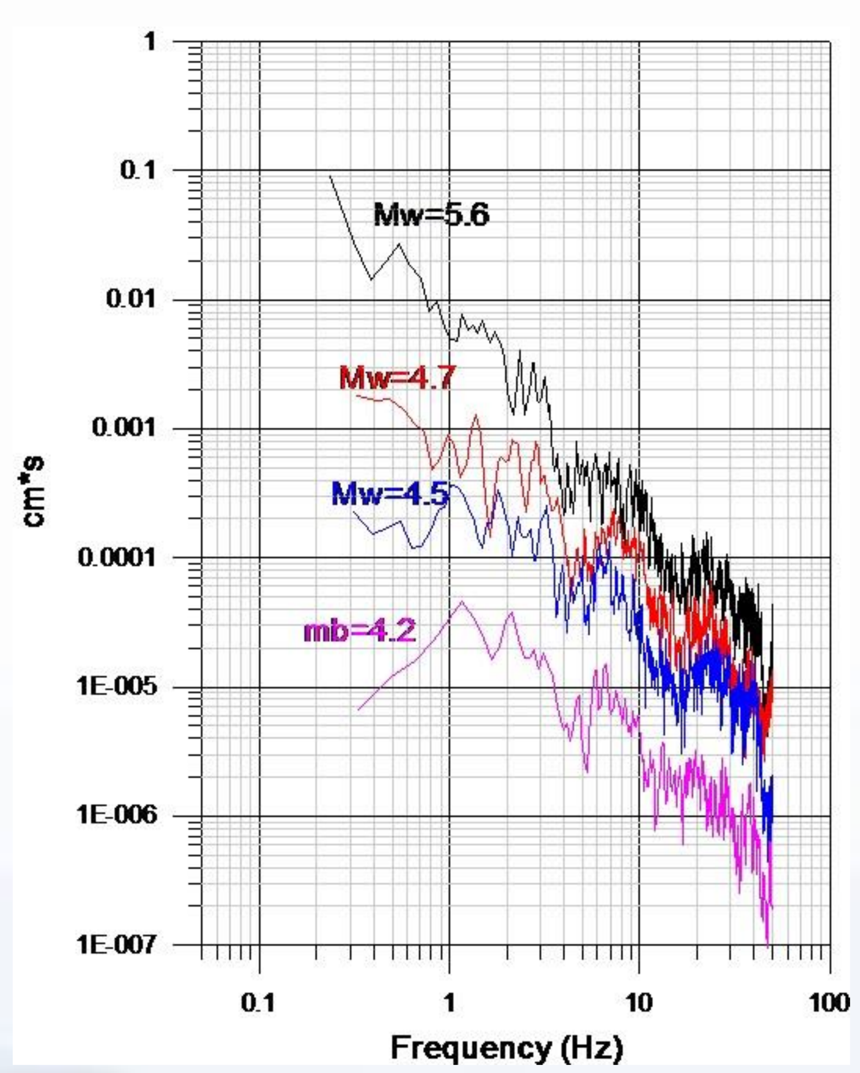
The observations could be assumed indicative for a low rupture velocity. The low rupture velocity can mean slow-faulting, which brings to slow release of accumulated seismic energy. The slow release of energy in principle does little to moderate damages.

That brought us the question - Could the 2012 M_w5.6 intraplate earthquake be considered as a type of slow earthquake?

To answer the question, we carried out further studies.

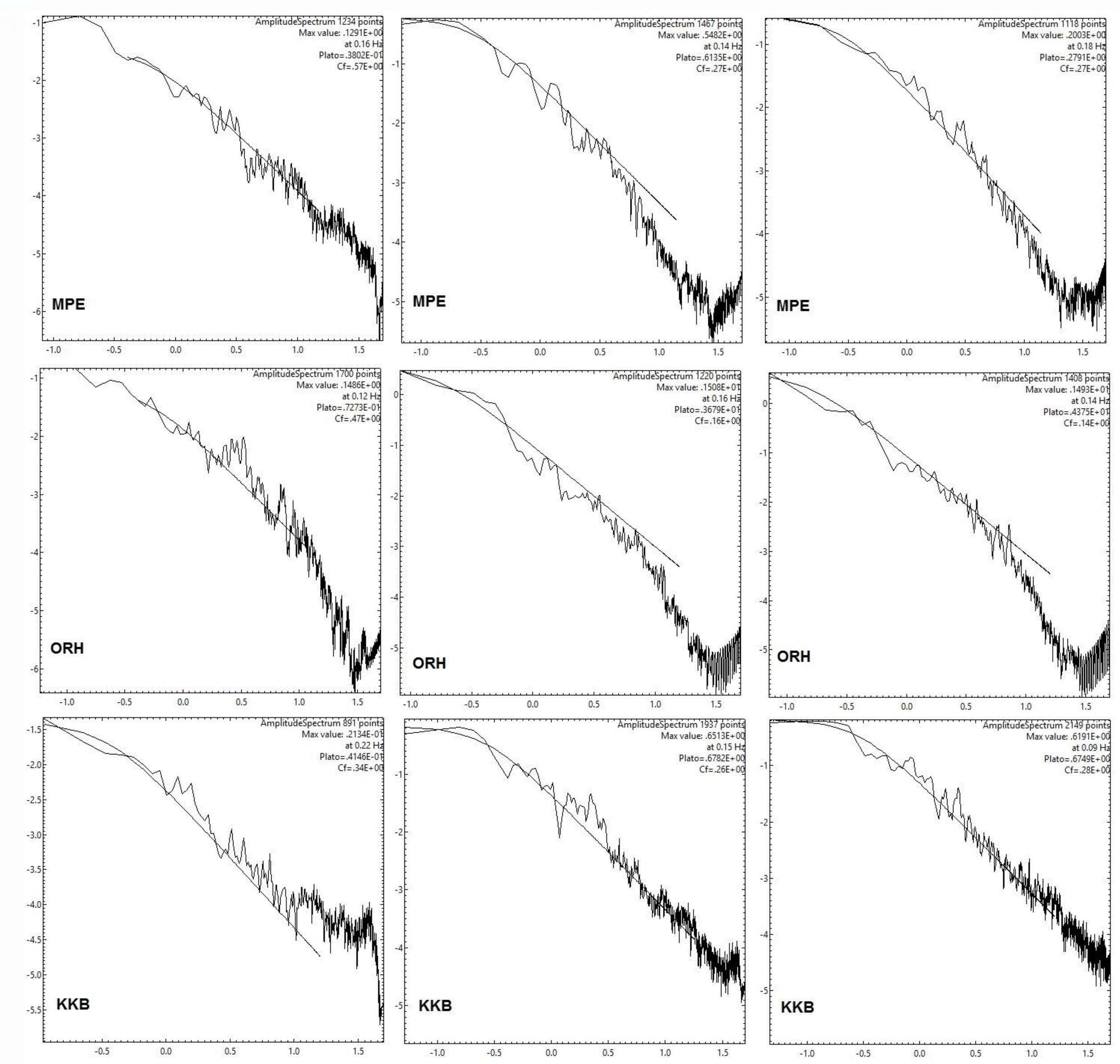
First we compared P-wave displacement spectrum for the 2012 M_w5.6 earthquake with spectra for three of the strongest aftershocks.

P-wave displacement spectra for the 2012 earthquake (M_w5.6; T_0=00:00:32 UTC (black line) and three of the strongest aftershocks (the first - M_w4.7, T_0=01:30:50 UTC (red line); the second m_b4.2, T_0=02:13:28 UTC (rose line) and the third M_w4.5, T_0=12:52:07 UTC (blue line) are shown in the figure to the right. The presented spectra are based on records at station MPE at an epicentral distance of about 100 km.



The figure shows low frequency content and not expressed spectrum plateau and corner frequency for the main shock while for the two aftershocks comparatively a well outlined flat long period displacement spectrum is observed. The specific P- wave displacement spectrum of the 2012 M_w5.6 earthquake could be assumed as indicative for a low rupture velocity. The low rupture velocity can mean slow-faulting, which brings to slow release of accumulated seismic energy. The slow release of energy does in principle small to moderate damages.

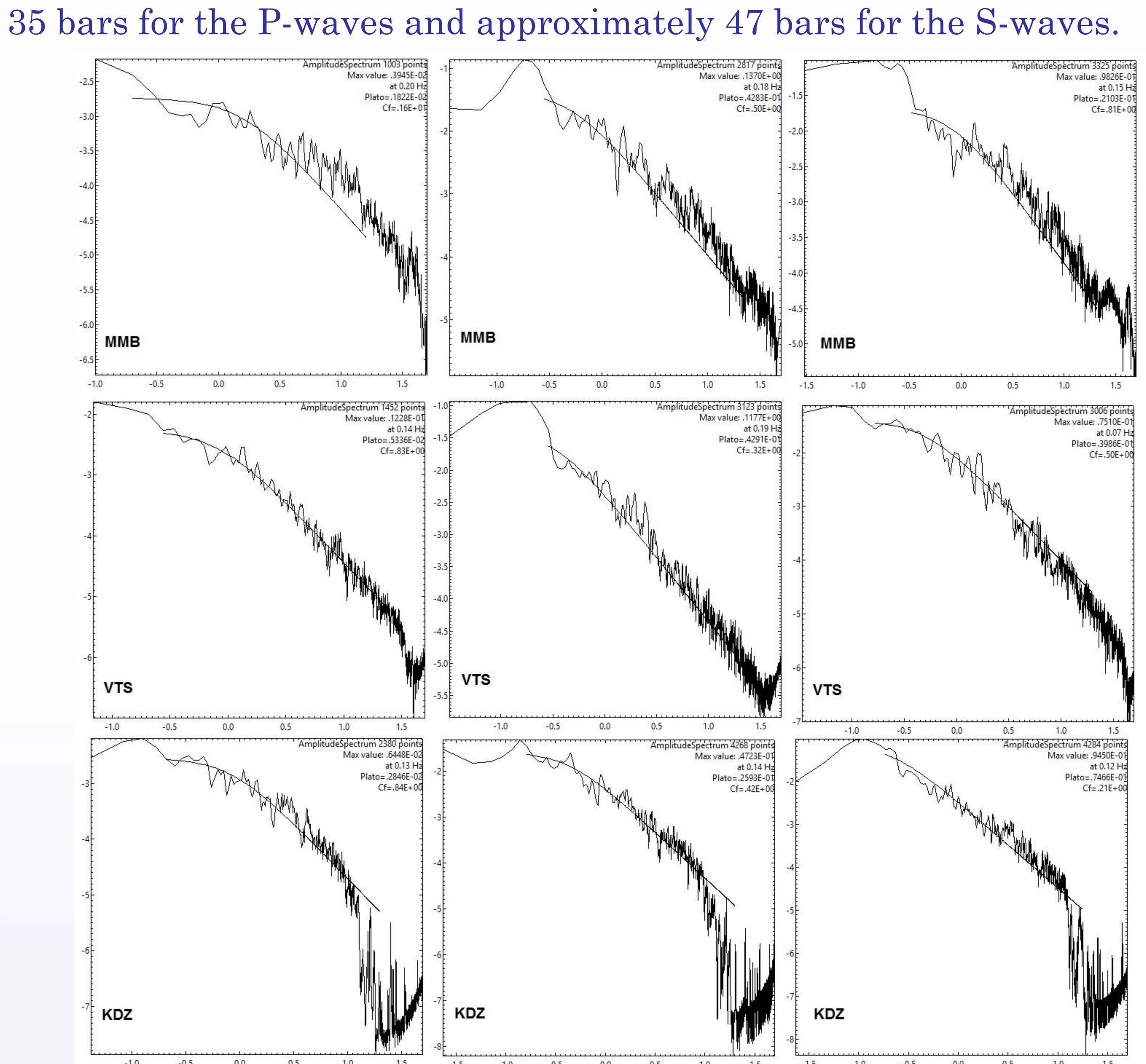
Then, following the model of Brune, we estimated the stress drop of the 2012 M_w5.6 earthquake using displacement spectra for P and S – waves. The spectra are generated on the base of record at 14 stations. Displacement spectra for P - wave and S - wave for the 2012 earthquake (M_w5.6; T_0=00:00:32 UTC) are presented in the figure below. The figures illustrates spectra for considered quake generated on the base of records at the stations situated at a distance of less than 200 km.



T_0=00:00:32 UTC, M_w5.6

The results (based on P - wave and S - wave spectra) show that the stress drop mean value is about 53 bars for the P-wave and approximately 280 bars for the S - wave. The stress drop values estimated for P - waves are within the expected range for moderate earthquake while for the S - waves are several times higher than the expected ones.

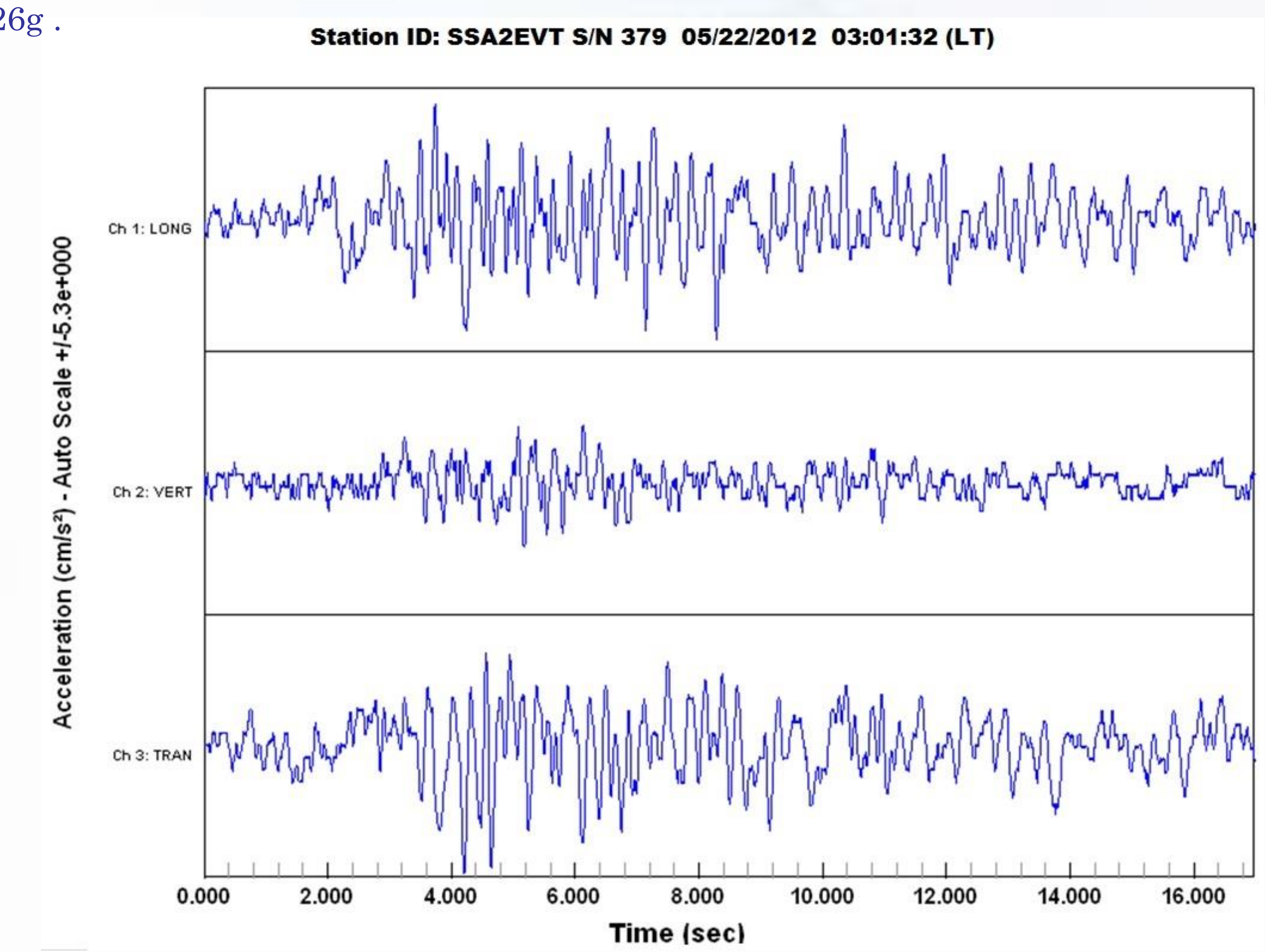
To compare the results we analyzed another moderate intraplate earthquake occurred on 24.05.2009 (M_w5.3) in Valandovo seismogenic zone (at a distance less than 150 km from the 2012 M_w5.6 quake). Displacement spectra for P - and S - waves for the earthquake are presented in the figures below. The results show that the values of the stress drop are about 35 bars for the P-waves and approximately 47 bars for the S-waves.



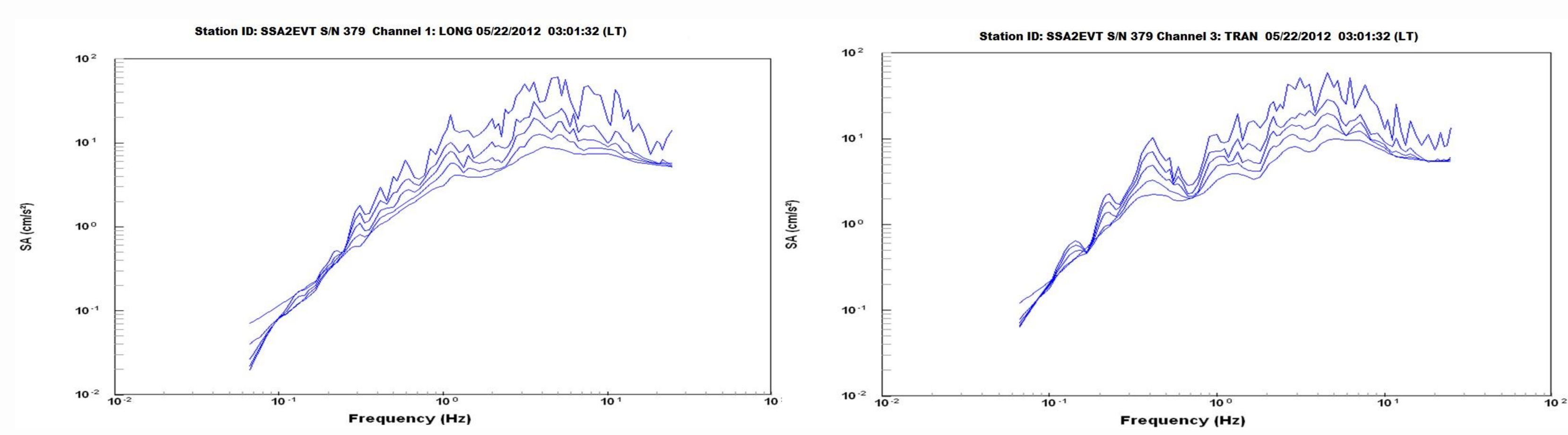
T_0=16:17:51 UTC, M_w5.3

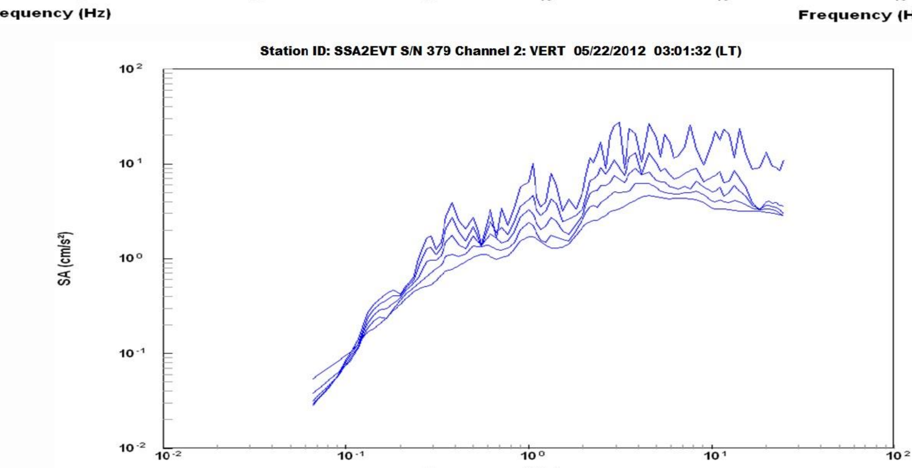
Finally, using records from the System of Accelerographs for Seismic Monitoring of Equipment and Structures (SASMES) deployed in Kozloduy NPP (at about 140 km from the 2012 M_w5.6 earthquake epicentre) response spectra are generated. The intended use of SASMES is to register and record the seismic motions in featured points of the building structure and equipment. This provides for the possibility to determine the parameters of the seismic motion at the locations of the mounting detectors – peak absolute accelerations, relative velocities and displacements; response spectra, etc.

The corrected accelerograms with an attached filter to 35 Hz for the 2012 earthquake (M_w5.6) are presented in the figures bellow. The maximum acceleration of accelerogram is: for horizontal component (L) - 0.0048g and for (T) - 0.0051g; for vertical component (V) - 0.0026g .



Spectra for 0, 2, 5, 10 and 20% damping are generated on the base of data from SASMES accelerograph installed at a free field. The spectra are presented below.





The figures illustrate:

- maximum acceleration spectrum (ZPA) for horizontal components (L) - 0.0054g; (T) - 0.0054g; and for vertical component (V) - 0.0031g;
- comparatively well outlined spectrum plateau between 0.7 Hz - 11.0Hz.

As a conclusion Our study could not give an unambiguous answer to the question - Can the 2012 M_w5.6 intraplate earthquake (that caused predominantly moderate damages and no casualties and severe injuries; the specific P-wave displacement spectrum of the earthquake is assumed as indicative for a low rupture velocity; the quake is characterized by high stress drop value for shear S-wave; and response spectrum with well outlined spectrum plateau between 0.7 Hz - 11.0Hz) be considered as a type of slow earthquake?

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