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Seismicity and seismic hazard modeling for Bulgaria

D. Solakov, S. Simeonova

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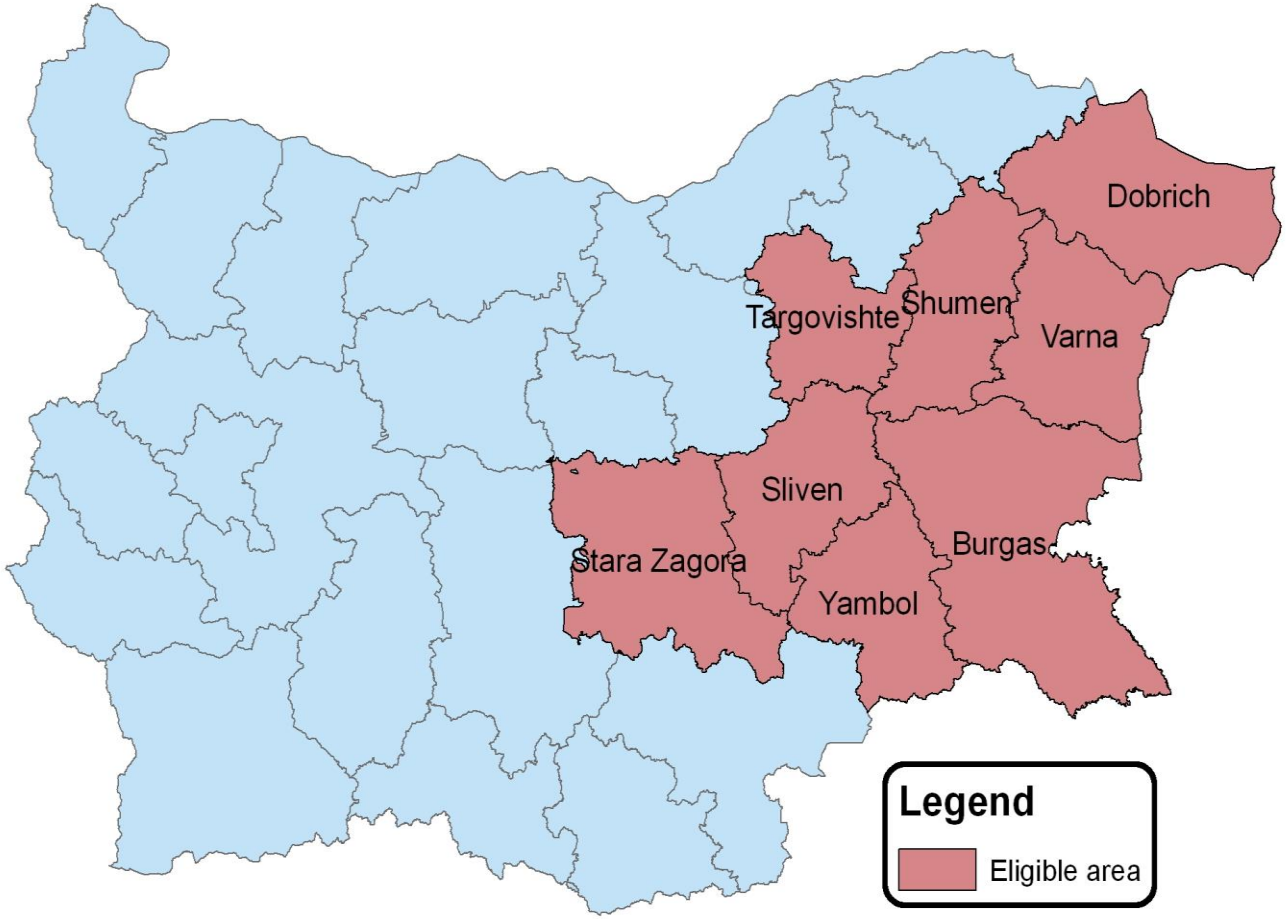
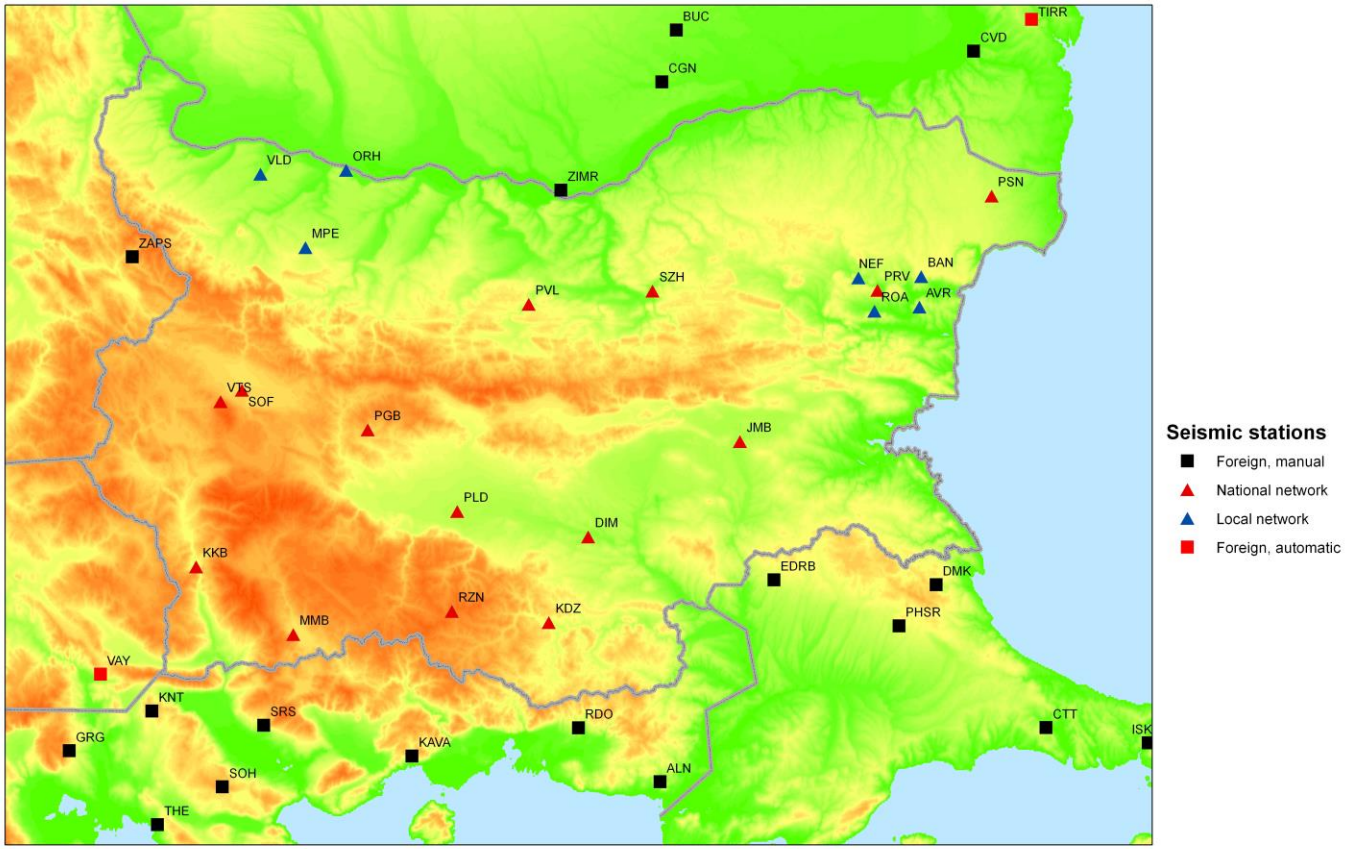


Bulgarian seismic network and foreign stations used in epicenter location



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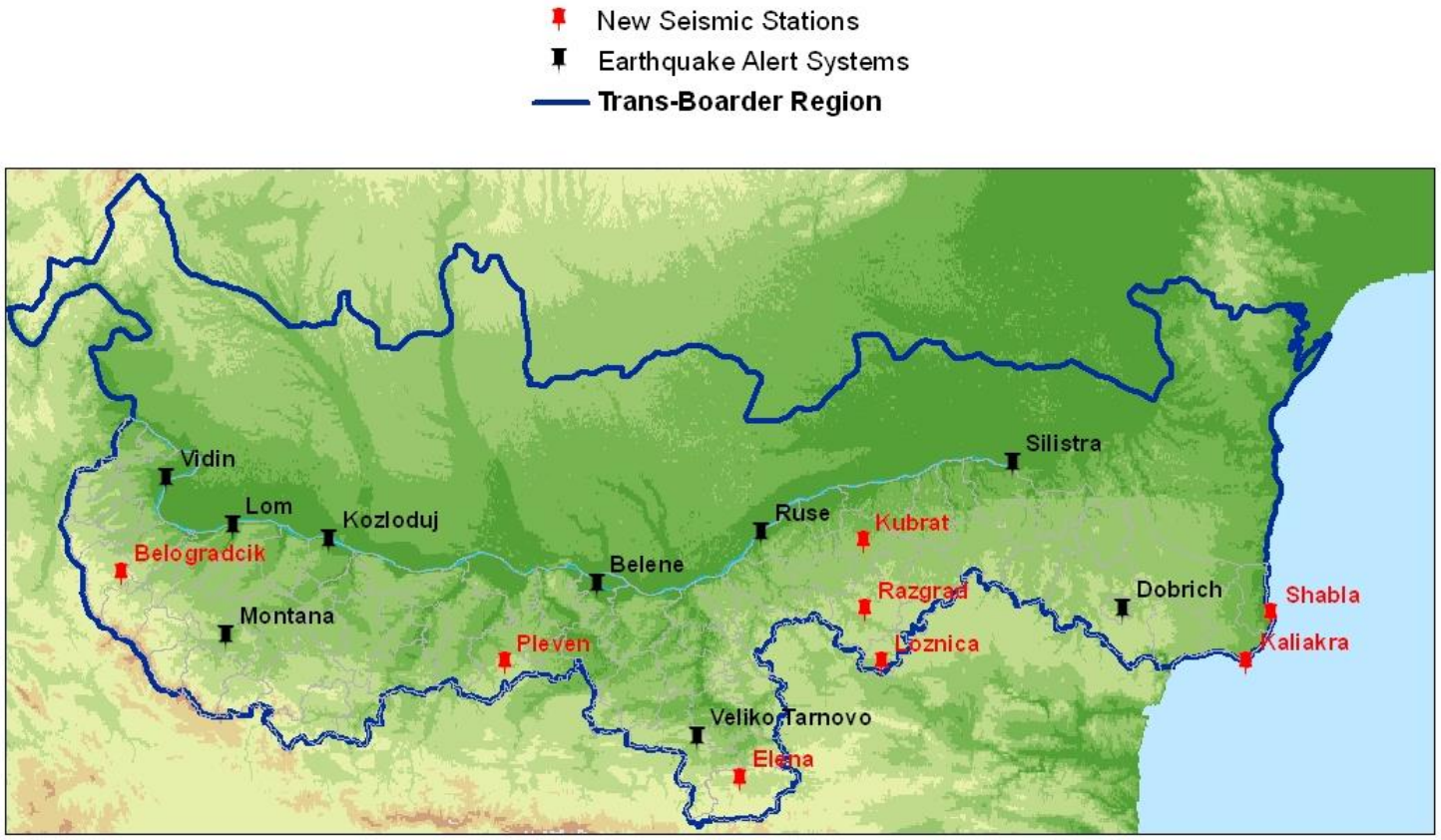
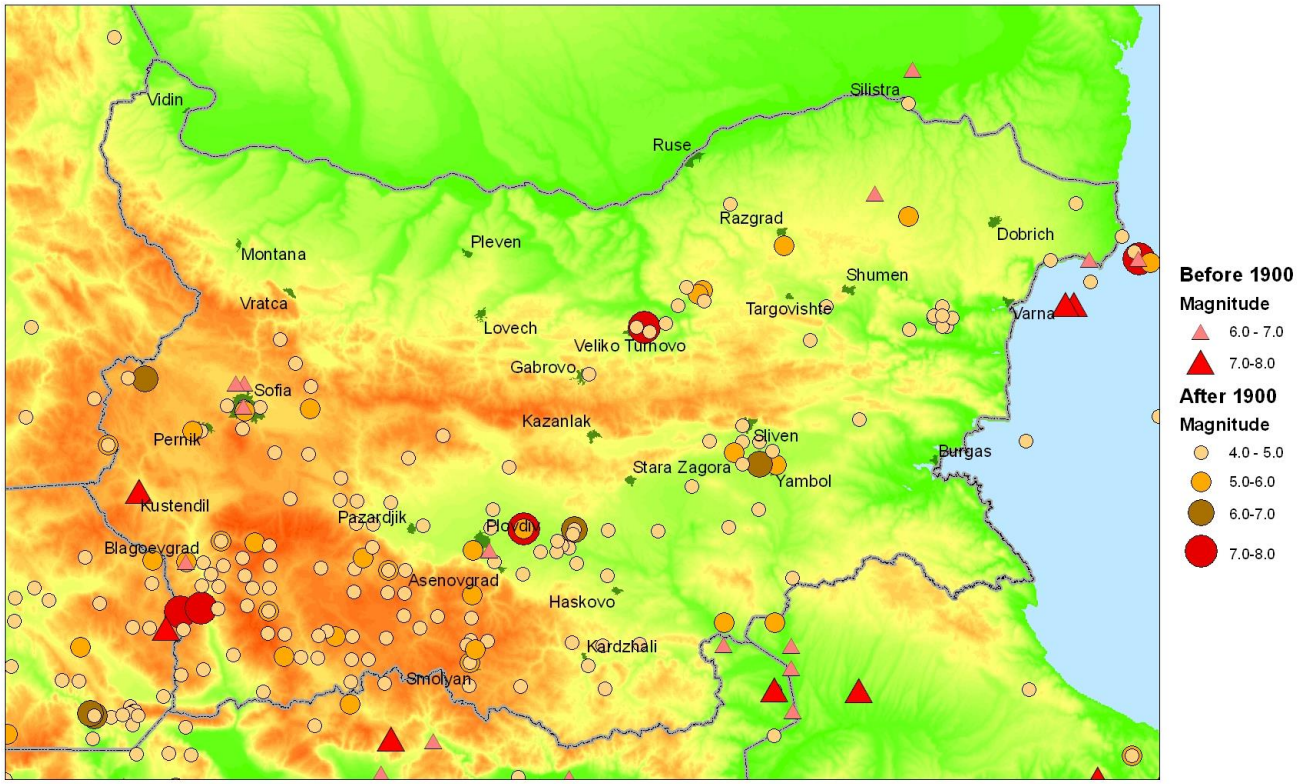
RO-BG transboarder project DACEA
Stations included in Early Warning System
(Bulgarian part)



Sismicity in Bulgaria and surroundings (M≥4.0)



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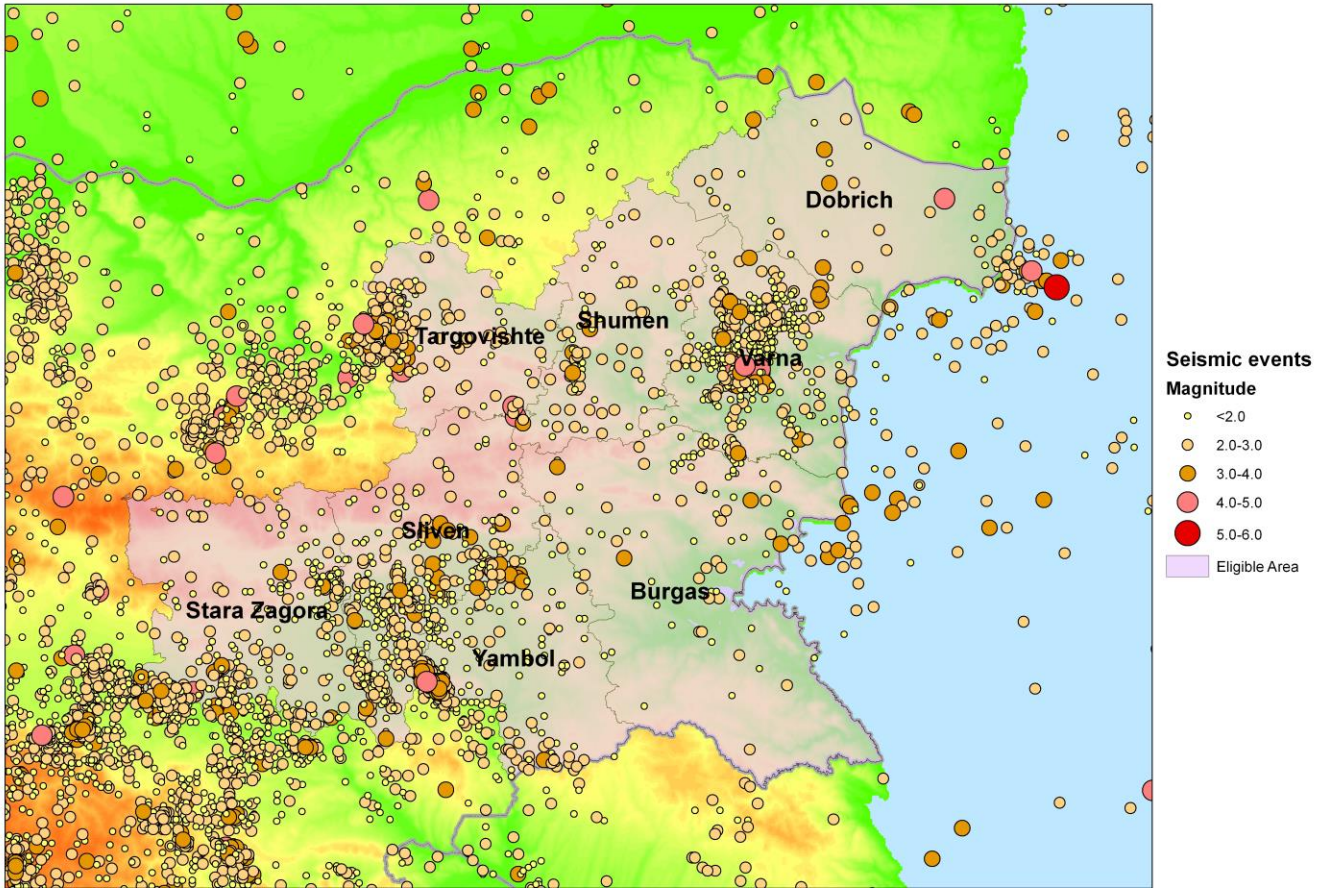
Epicentral map for Bulgaria and surroundings (after 1980, all recorded quakes)



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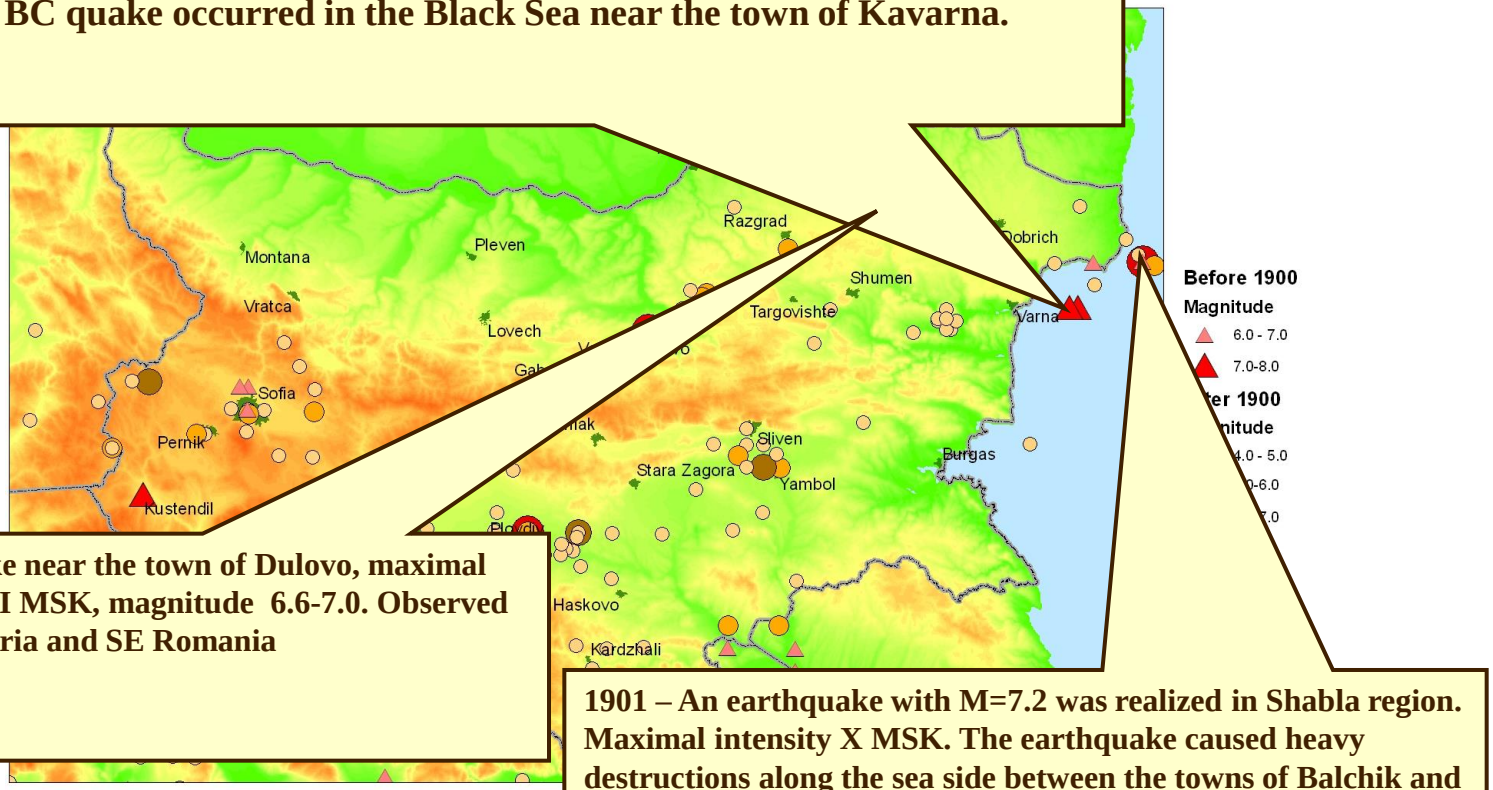
Historical earthquakes

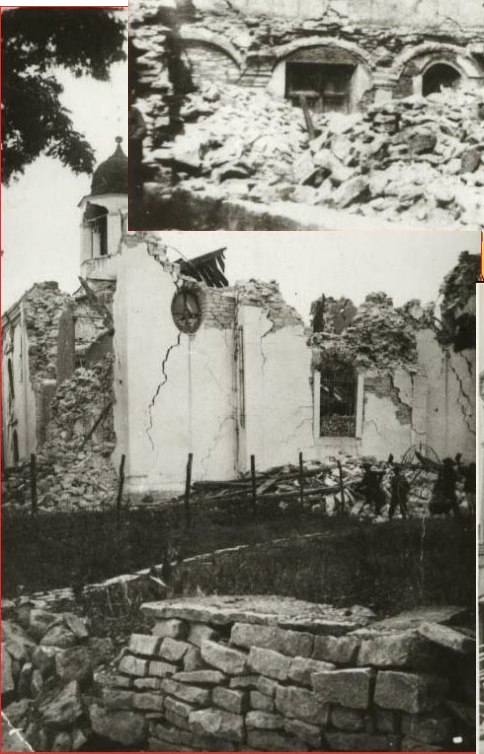
The first well documented earthquake on the territory of Bulgaria is the first century BC quake occurred in the Black Sea near the town of Kavarna.

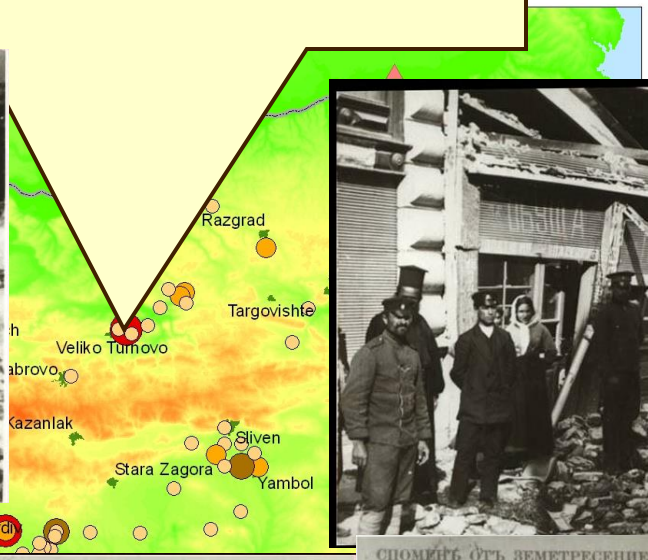


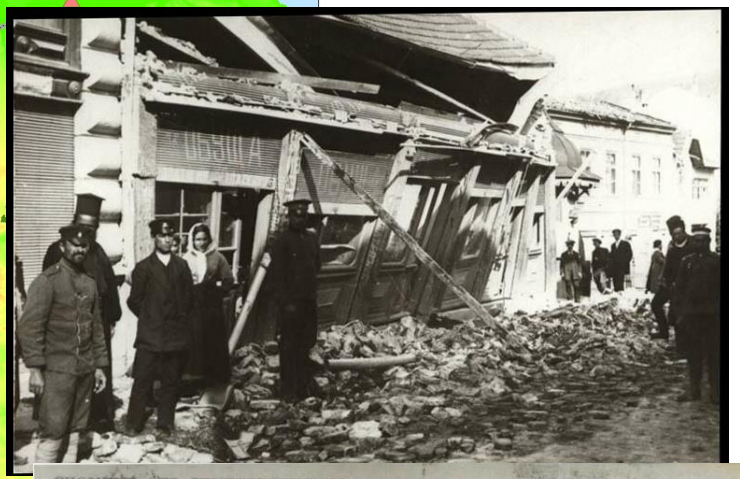
1892 г. – earthquake near the town of Dulovo, maximal intensity Imax=VIII MSK, magnitude 6.6-7.0. Observed effects in NE Bulgaria and SE Romania

1901 – An earthquake with M=7.2 was realized in Shabla region. Maximal intensity X MSK. The earthquake caused heavy destructions along the sea side between the towns of Balchik and Shabla. The felt area approximately is 610 000 km^2.

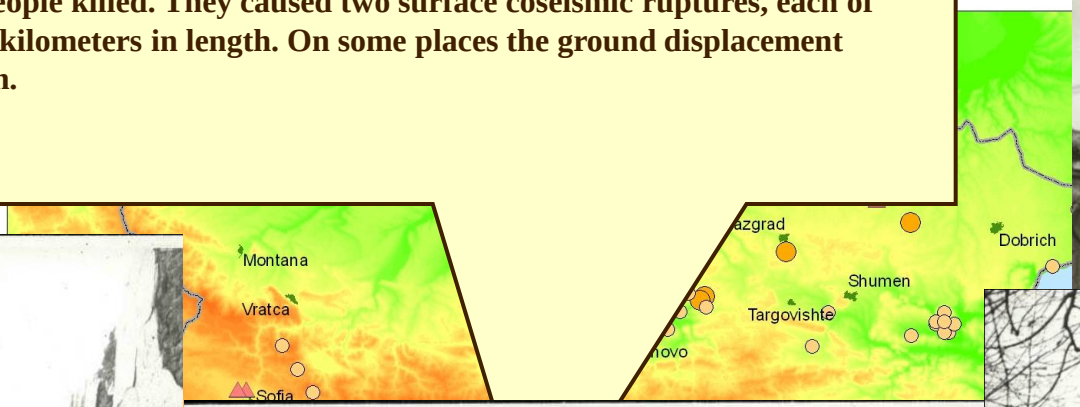
In 1913 – near the town of Gorna Oryahovitsa occurred an earthquake with M_S=7.0, epicentral intensity – IX-X. Destructions - Gorna Oryahovitsa, up to 95%; V. Tarnovo, Dolna Oryahovitsa, Lyaskovets -up to 80%. Felt area is about 400 000 km^2



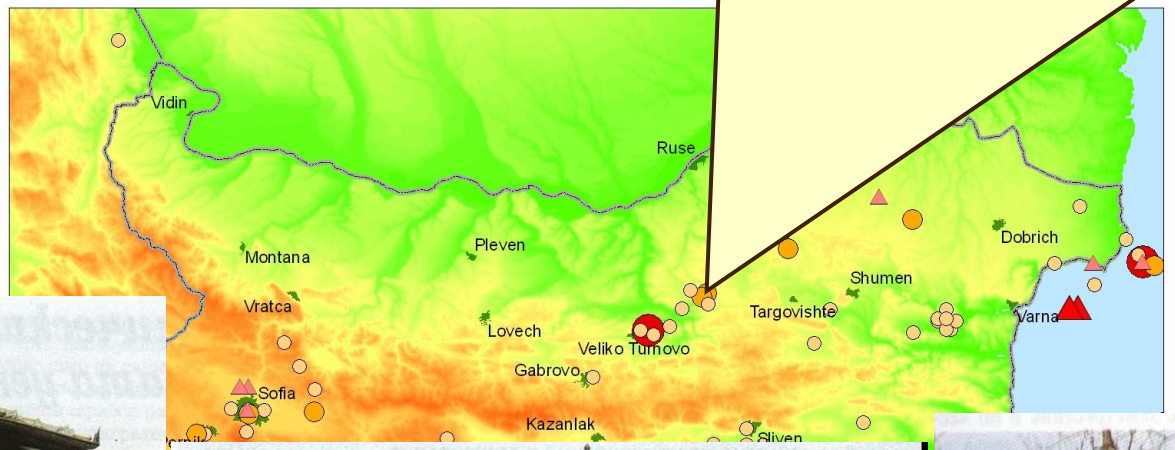


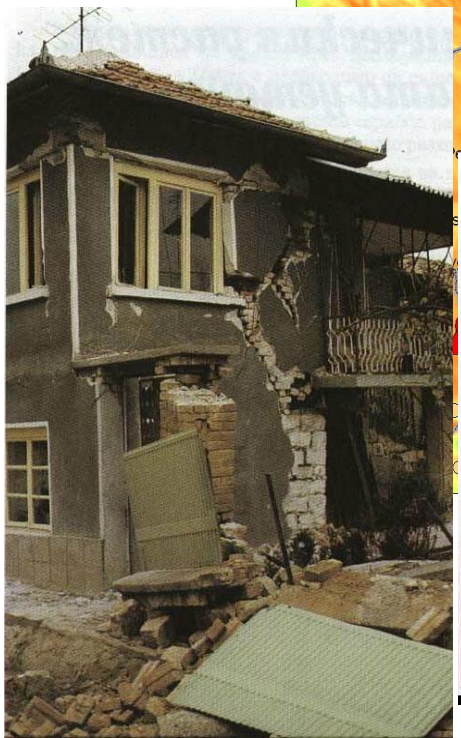


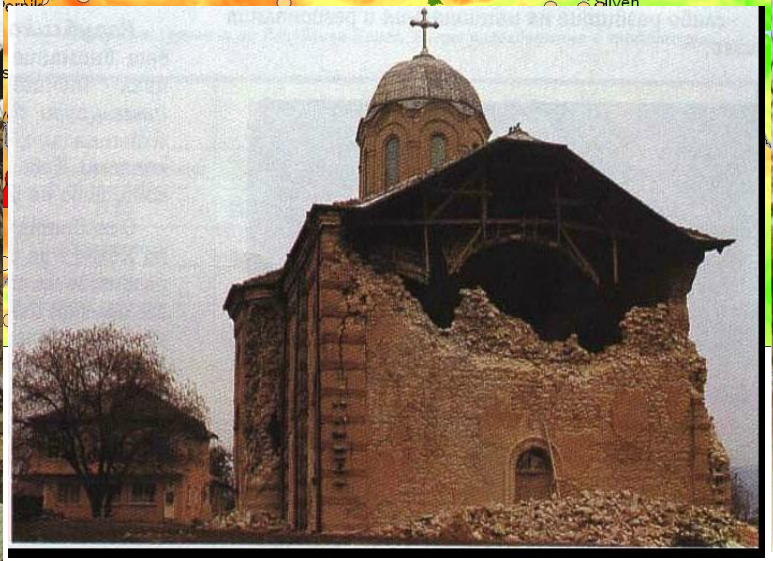
Along the Maritca valley (central part of Bulgaria), in 1928 a sequence of three destructive earthquakes occurred (the strongest earthquake is of magnitude M=7.0). Many towns and villages were strongly affected. 74000 buildings were completely destroyed and 114 people killed. They caused two surface coseismic ruptures, each of them several tens of kilometers in length. On some places the ground displacement reaches up to 1.5-2 m.



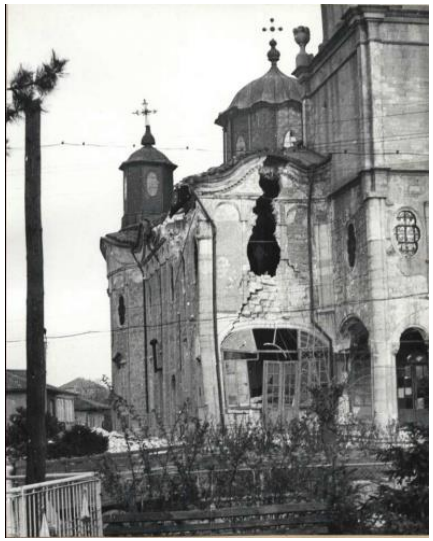
However, no such large earthquakes occurred in Bulgaria since 1928. The 1986 earthquake of magnitude MS=5.7 occurred in the central northern Bulgaria (near the town of Strazhitza) is the strongest quake after 1928. 1986 – two earthquakes in the region of Strazitsa, 21.02.1986, M=5.3 and 07.12.1986, M=5.7. Partially or totally destroyed – 15000 buildings, 2 victims, 60 injured. The earthquake was felt in the area of 180 000 km^2.

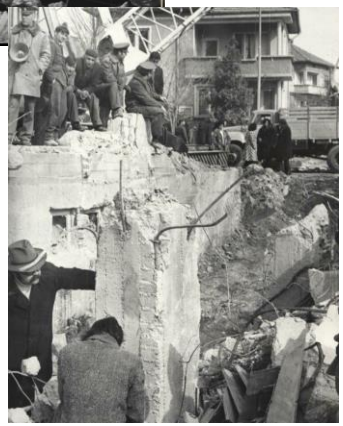


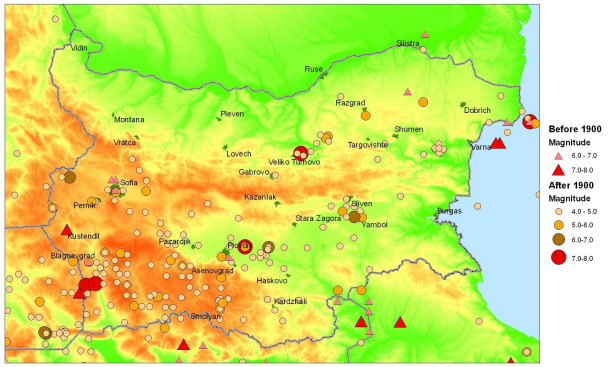




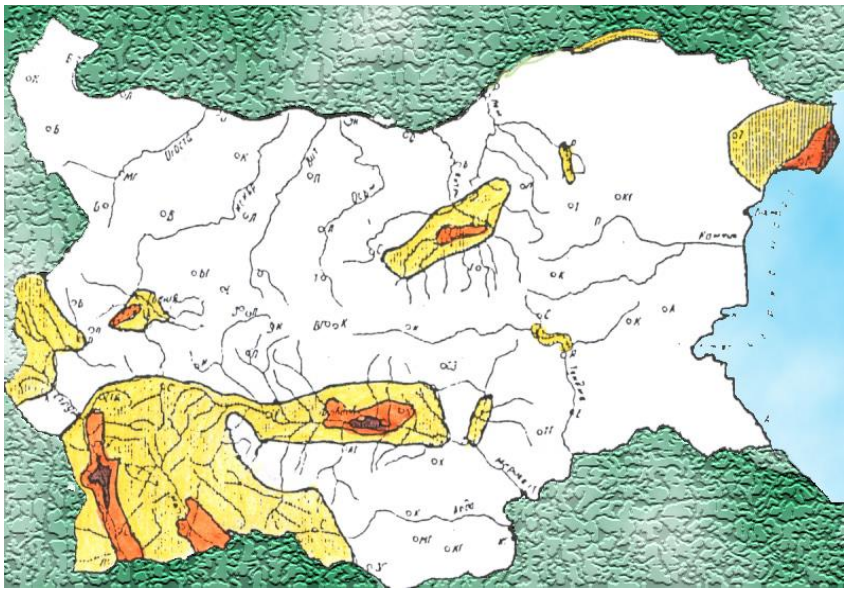
04.03.1977 Vrancea intermediate earthquake, M=7.2, depth 90-110 km, epicentral intensity VIII-IX. Partially or totally destroyed – 8470 buildings, 125 victims. The heavy consequences are due to non adequate housing constructions and bad local site conditions.





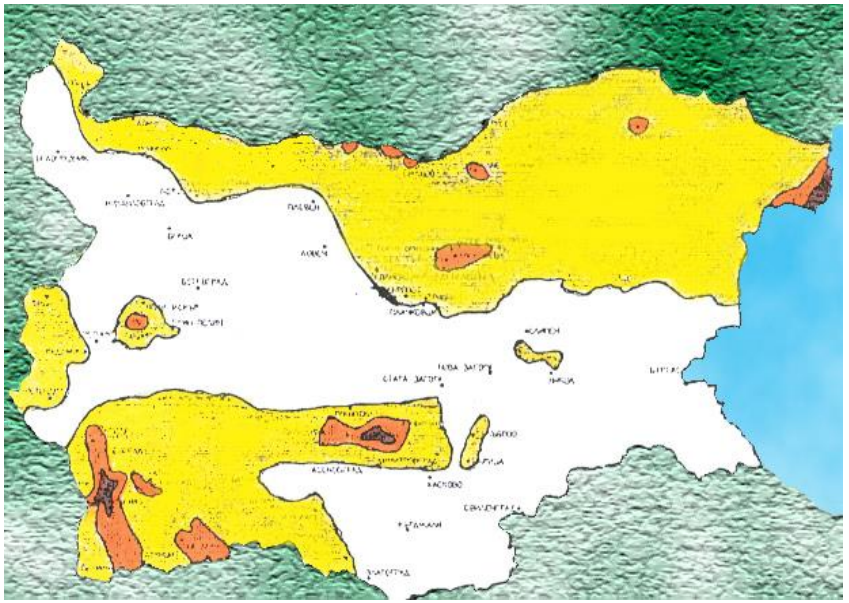


SEISMIC ZONING MAP 1961-1964

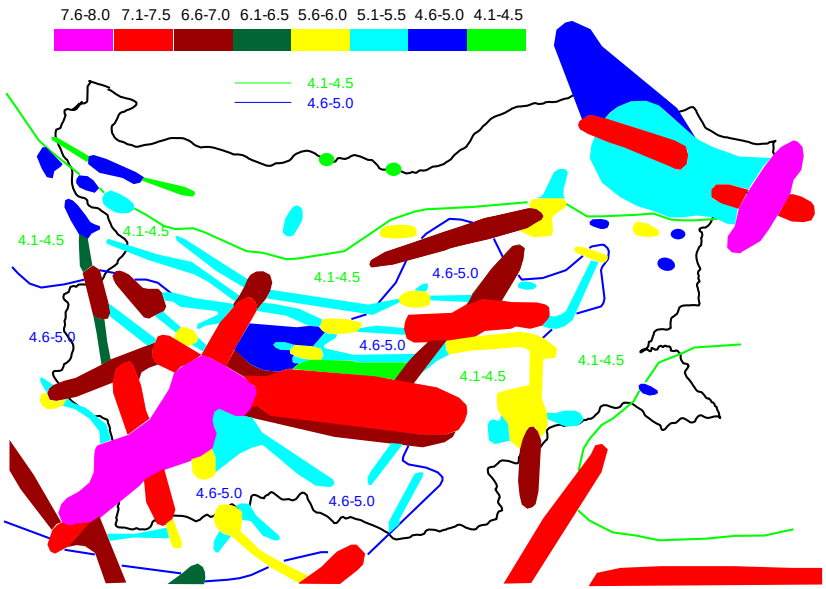


First building code - 1957

SEISMIC ZONING MAP 1977



SEISMIC SOURCES



SEISMIC ZONING MAP – 1987, return period 1000 years

PROBABILISTIC SEISMIC HZARD ASSESSMENT

The probability that a ground motion parameter, **Z**, at a given site, will exceed a specified level, **z**, during a given time period, **t**, is given by the expression:

$$P(Z \geq z \mid t) = 1 - e^{-\nu(z)t} \leq \nu(z)t$$

where ν**(z)** is the average frequency during time period **t** at which the level of ground motion parameter **Z** exceeds **z** at the site, resulting from earthquakes in all sources in the region. The frequency of exceedance, ν**(z)** is calculated by**:**

$$\nu(z) = \sum_n \alpha_n(m^0) \int_{m^0}^{m^u} \int_0^{\infty} f(m)\, f(r \mid m) P(Z \geq z \mid m, r)\, dr\, dm$$

$\alpha^{\mathbf{n}}$**(m$^{\mathbf{o}}$)** is the frequency of earthquakes on source **n** above a **m$^{\mathbf{o}}$** (min. mag. of ing. Importance);
f(m) is the PDF for events between **m$^{\mathbf{o}}$** and maximal event for the source **m$^{\mathbf{u}}$**;
f(r|m) is the PDF for distance to the earthquake rupture;
P(Z≥z | m,r) is the probability that for a given magnitude **m** earthquake at a distance **r** from the site, the ground motion exceeds level **z**.

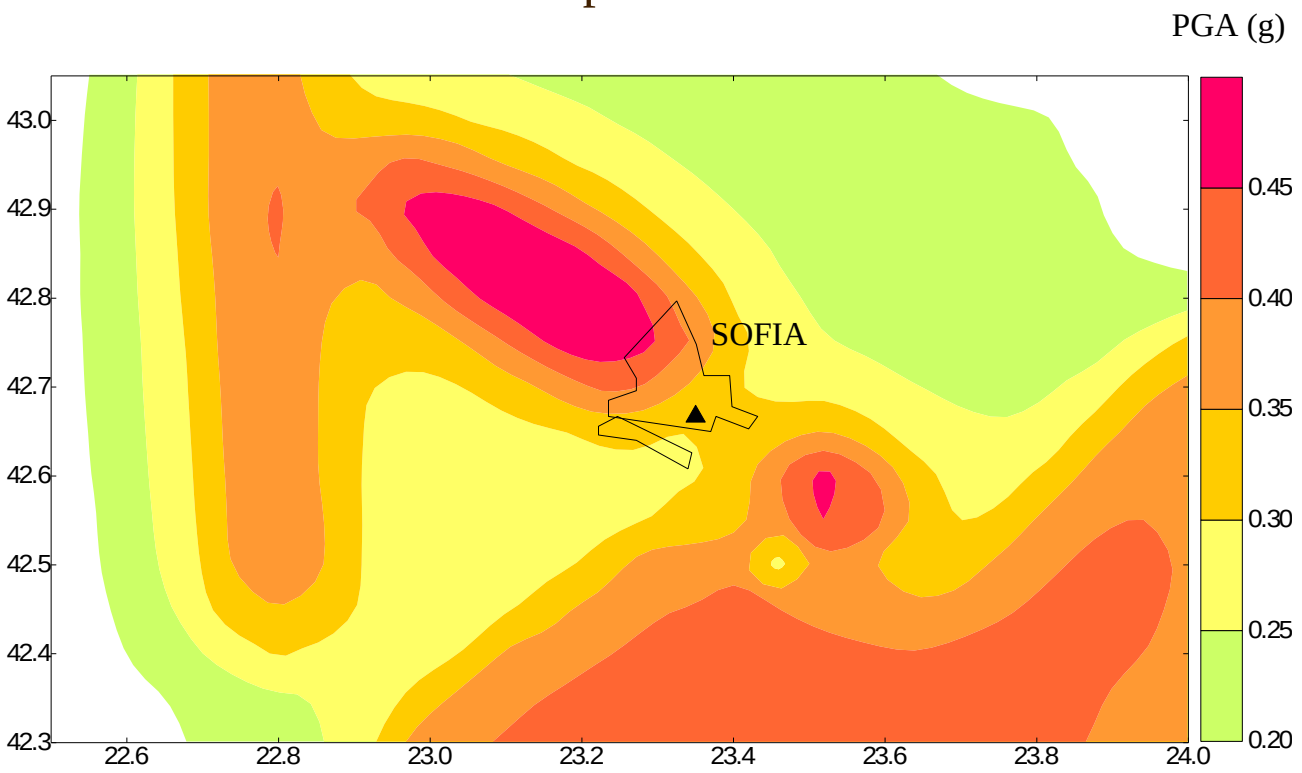
Hazard analysis for high risk facility sites

PROBABILISTIC AND DETERMINISTIC

Detailed investigations at least in 25-30 km regions
Logic tree approach
Monte Carlo approach

Hazard assessment for parts of Bulgarian territory

Seismic hazard for the region of Sofia, 1000 years return period



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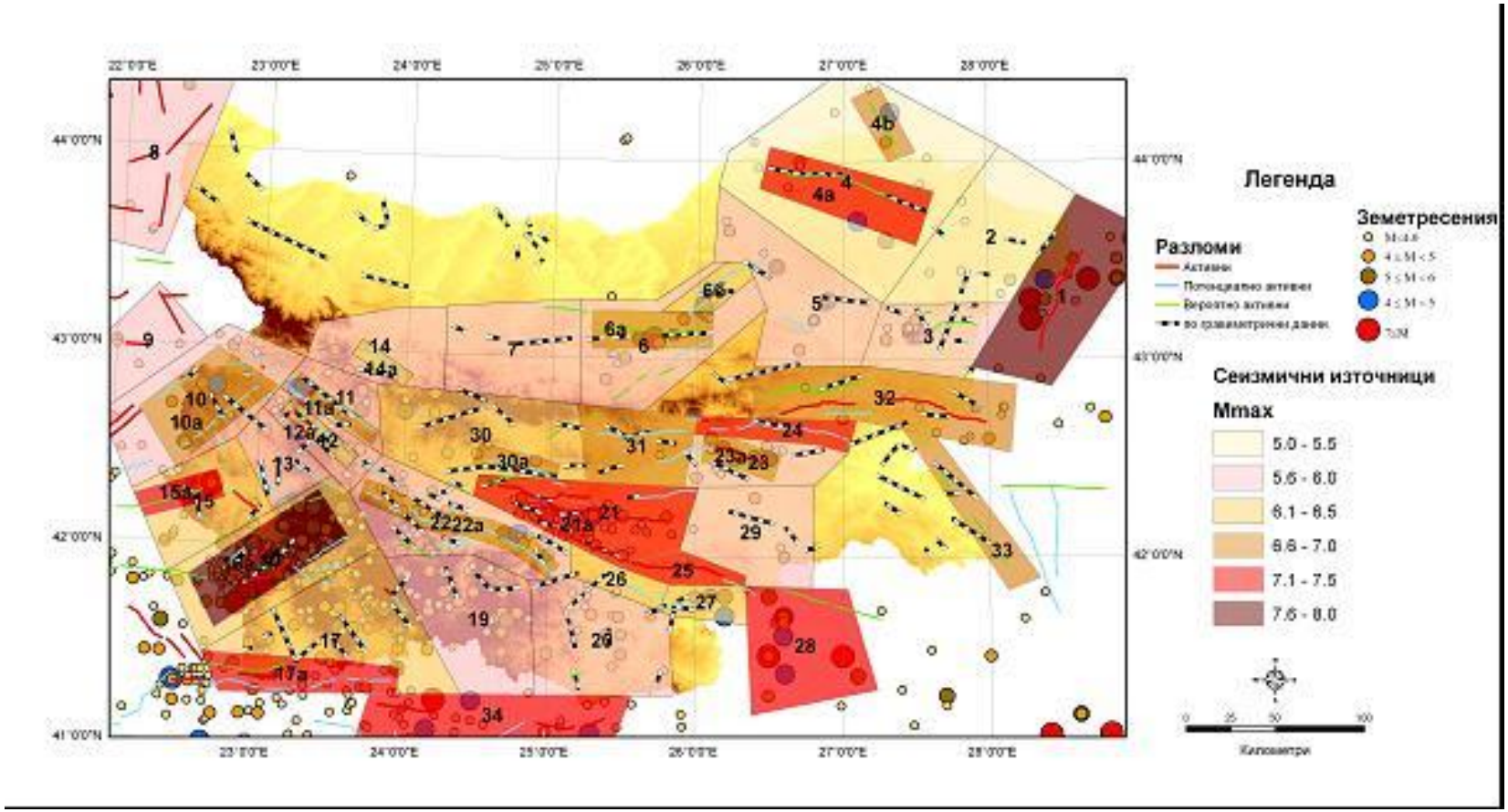
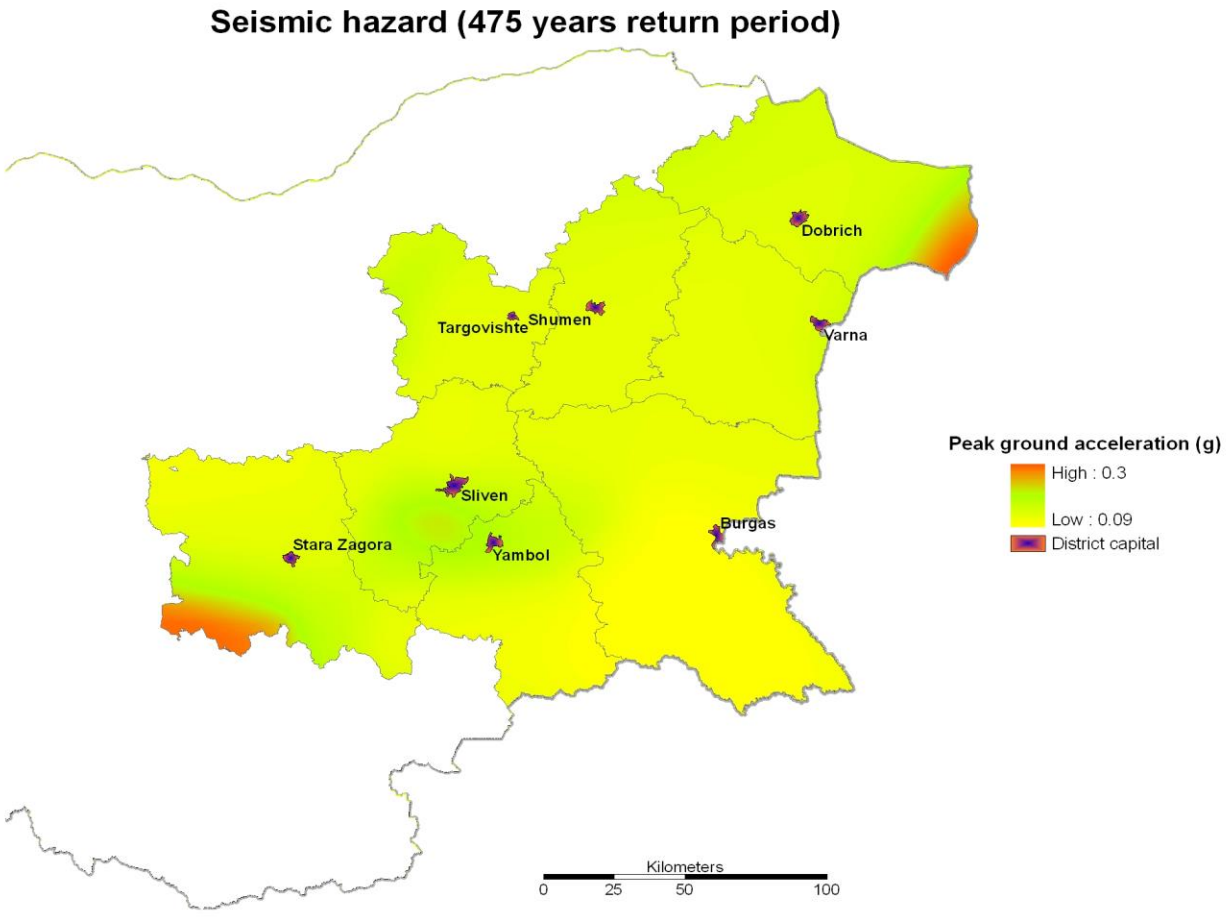
COMPLEX GEOLOGO-GEOPHYSICAL AND SEISMOLOGICAL MAP




Seismic hazard (475 years return period)
Dobrich
Targovishte
Shumen
Varna
Sliven
Burgas
Stara Zagora
Yambol
Peak ground acceleration (g)
High : 0.3
Low : 0.09
District capital
Kilometers
0
25
50
100
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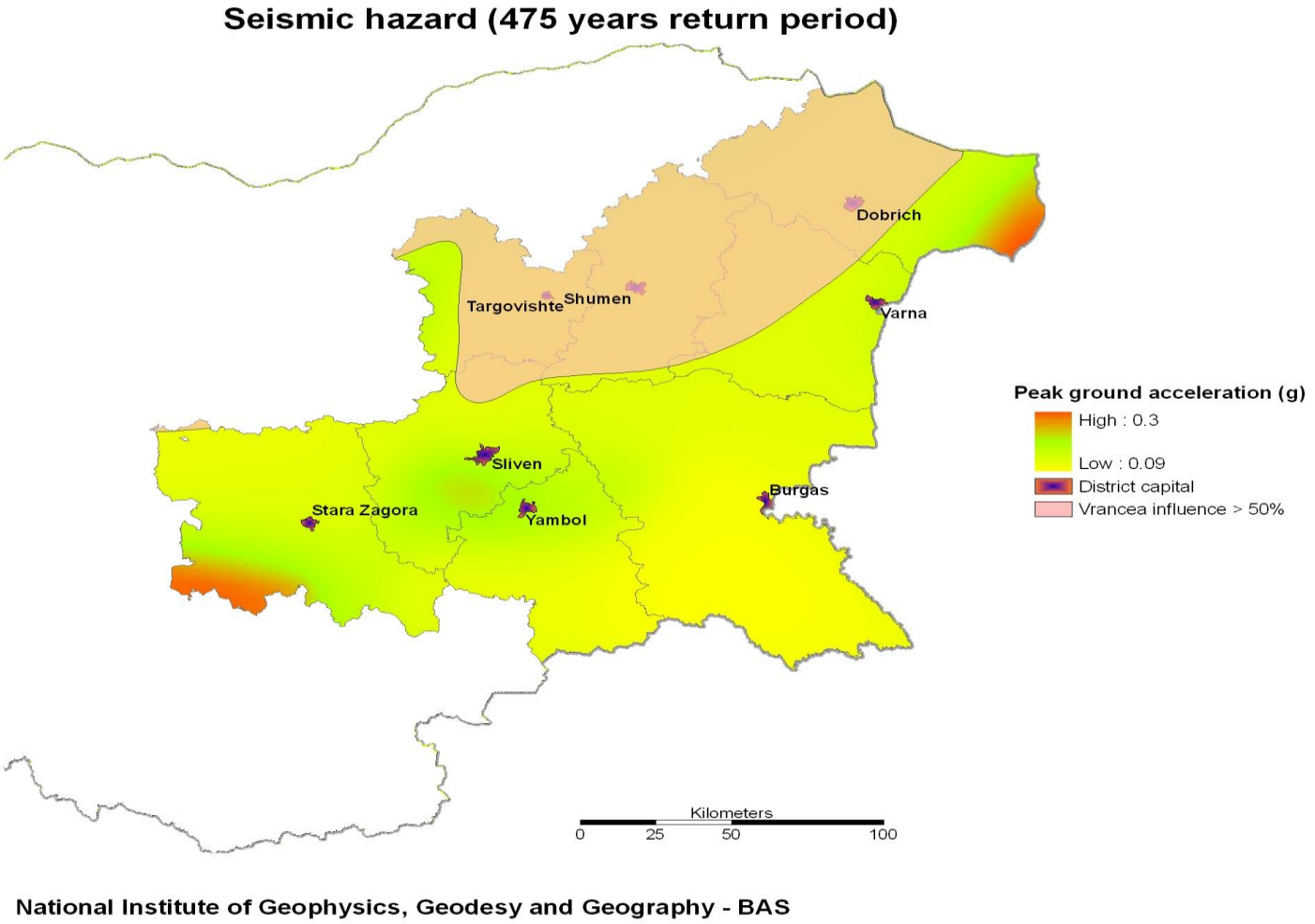
Influence of intermediate Vrancea earthquakes



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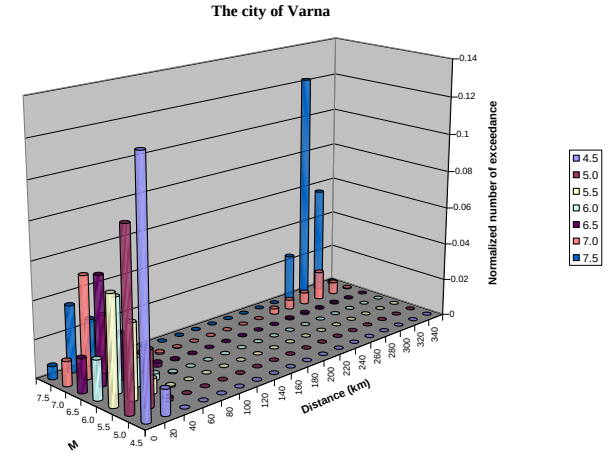
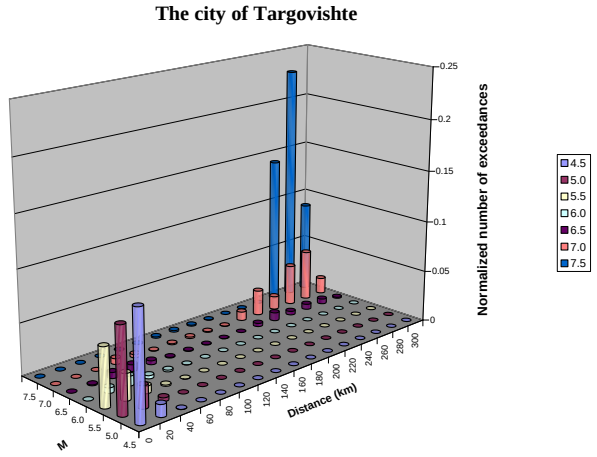
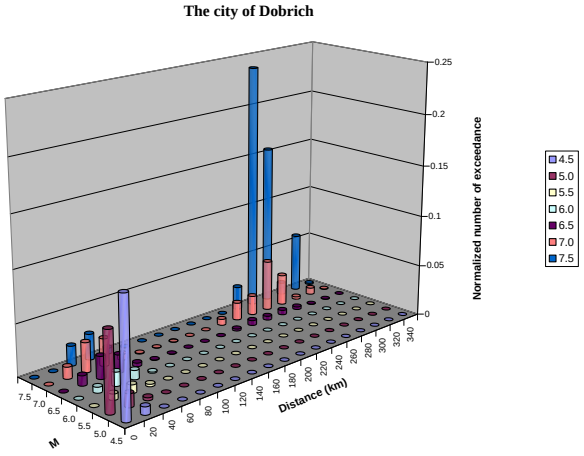
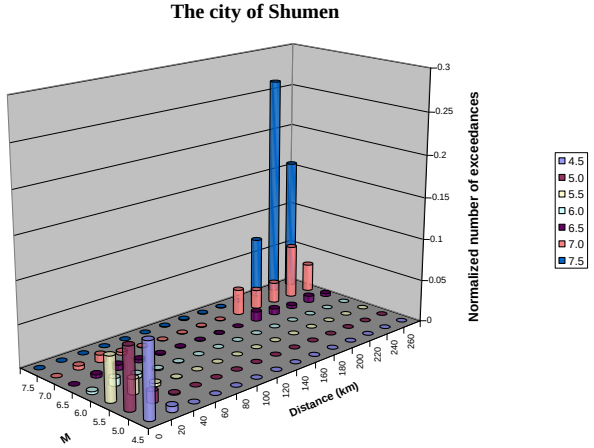
DEAGGREGATION OF THE 475 YEARS HAZARD – Northern cities

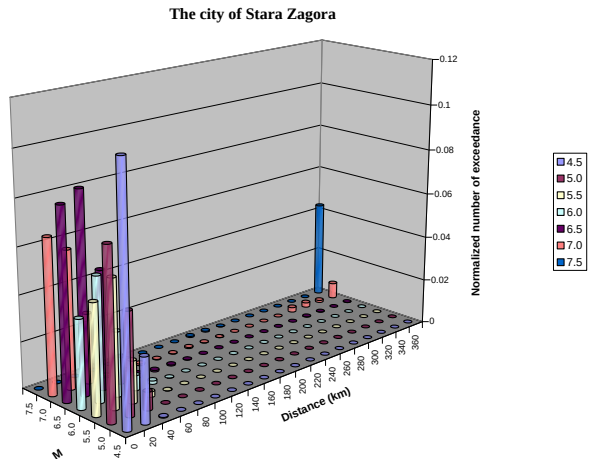


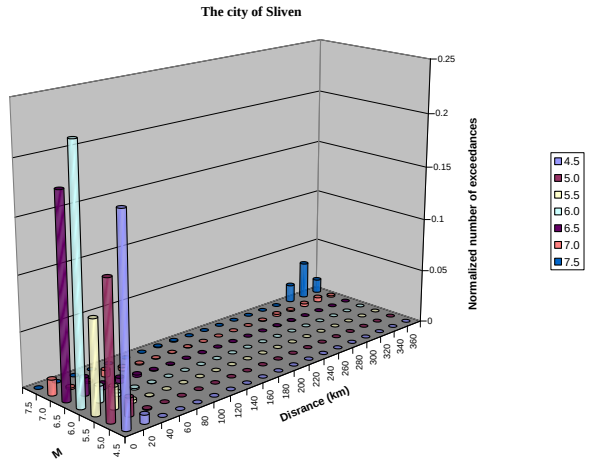


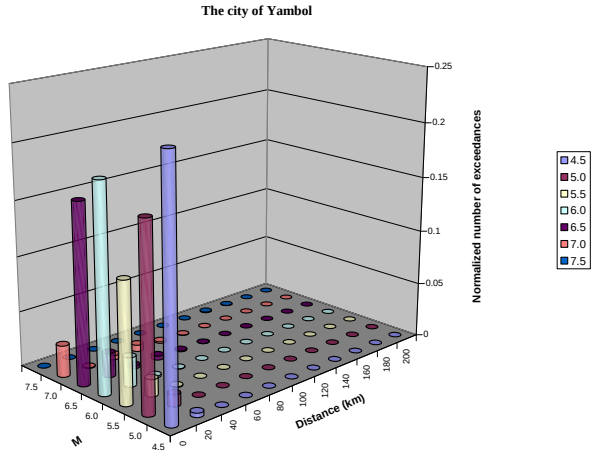


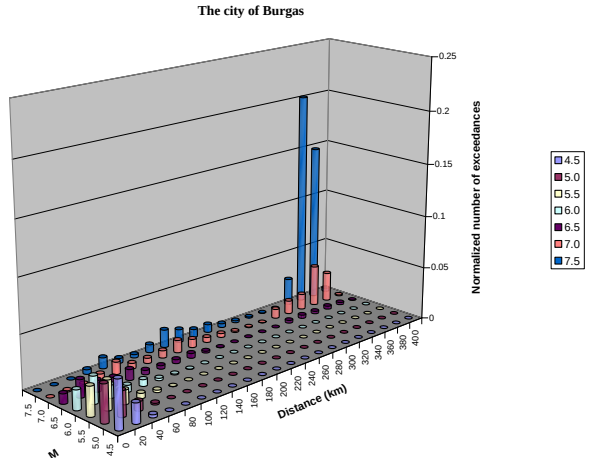


DEAGGREGATION OF THE 475 YEARS HAZARD – Southern cities









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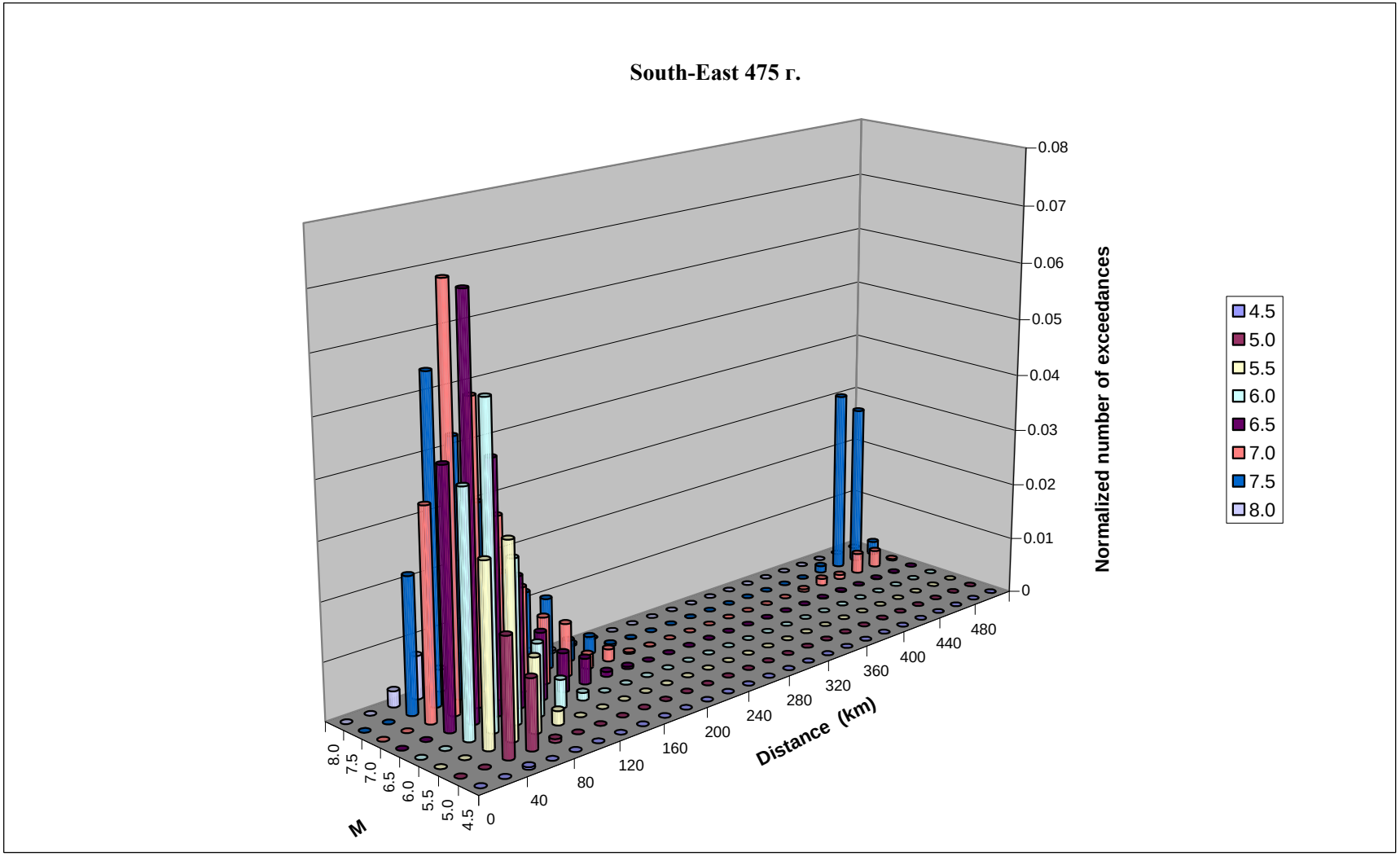
DEAGGREGATION OF THE 475 YEARS HAZARD – South-Eastern part



THANK YOU FOR ATTENTION