The Abdus Salam
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United Nations
Educational, Scientific
and Cultural Organization

International Atomic
Energy Agency

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Probabilistic Seismic Hazard Assessment for the Bohunice and Mochovce Nuclear Power Plant (Slovakia) Sites

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Introduction

Previous estimates in terms of PGA and PSA were based on deterministic analysis

The International Atomic Energy Agency has recommended that the standard PSHA should be performed for both sites

Introduction

The PSHA was performed in compliance with

- 50-SG-S1 (Rev. 1) (IAEA, 1991) and its revised version
- TECDOC - 724 (IAEA, 1993)
- IAEA Review Mission to Slovakia ... (IAEA, 1994, 1998)

Outline

The PSHA includes:

- compilation of the seismological database
- compilation of the geological database
- construction of the seismotectonic model
- determination of attenuation
- probabilistic computation of the UHS
- de-aggregation of the hazard computation and determination of hazard characteristics

Seismological database

Data on macroseismically observed earthquakes

Data on instrumentally recorded earthquakes

Data on microearthquake activity in the near region

Seismological database

Data on macroseismically observed earthquakes

The whole far region, i.e. the asymetric area of a size of at least 150 km from site, includes some parts of Slovakia, Hungary, Austria, the Czech Republic and Poland

Sources

Historical earthquakes

- recent studies that use primary sources
- descriptive earthquake catalogues
- parametric earthquake catalogues

Seismological database

Data on macroseismically observed earthquakes

Sources

Recent earthquakes

- recent studies that use macroseismic questionnaires
- descriptive catalogues and other literature
- bulletins of seismometric observations

Seismological database

Data on macroseismically observed earthquakes
was compiled in two steps:

1. Separate compilation of catalogue
of macroseismically observed earthquakes for
Slovakia, Hungary, Austria, the Czech Republic and Poland

2. Merging of the catalogues into one file

Seismological database

Slovakia

Historical earthquakes

- recent studies exist on a few key earthquakes only, e.g.

  June 28, 1763 - Szeidovitz (1986),
  Brouček et al. (1991)
  June 5, 1443 - Labák et al. (1996),
  Labák (1996)

- parametric catalogues:
  Labák (2001)

Seismological database

The June 5, 1443 Central Slovakia earthquake

Kárník et al (1957) catalogue:

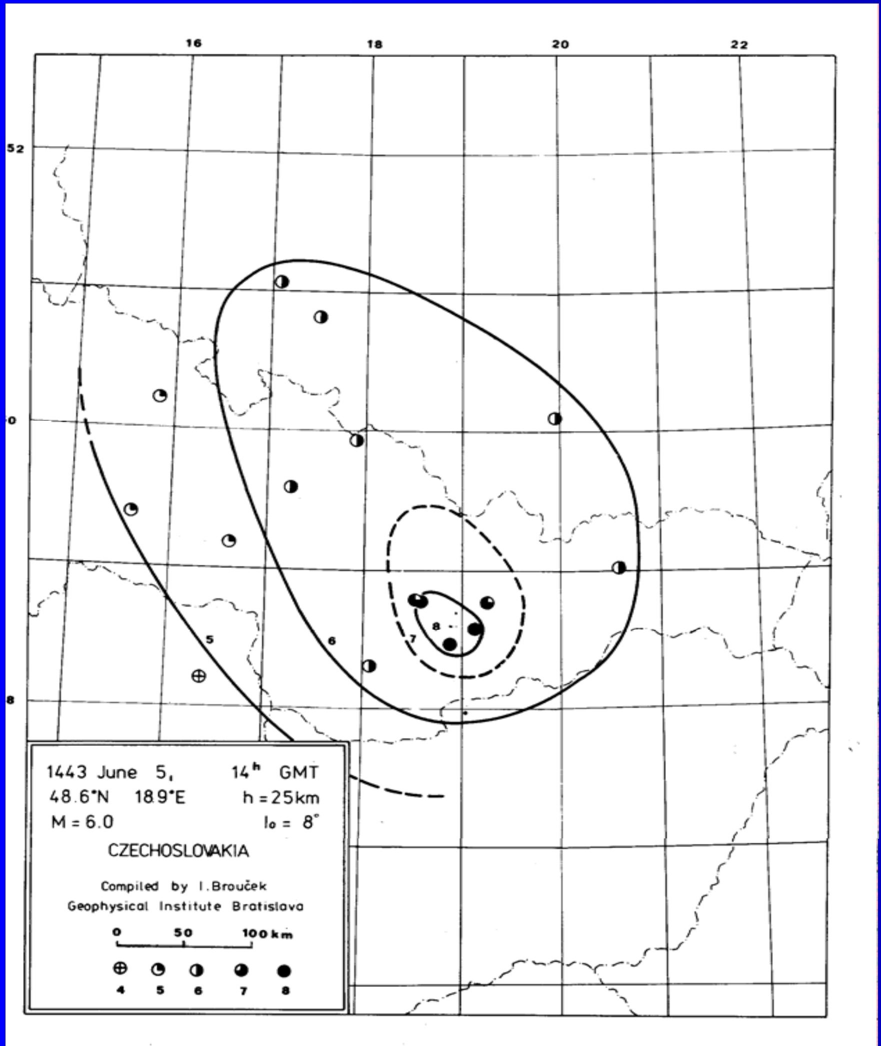
Date	**Region**	**I_0 [MCS]**
1441	Banská Štiavnica 48.4N 18.9 E	9
29.5. 1443	Hungary, Austria, Silesia, Poland Bohemia	?
5.6.1443	Silesia or Central Slovakia	9

Réthly (1952)

1441	Banská Štiavnica	?
5.6.1443	Slovenská Ľupča	?

Seismological database

The June 5, 1443 Central Slovakia earthquake

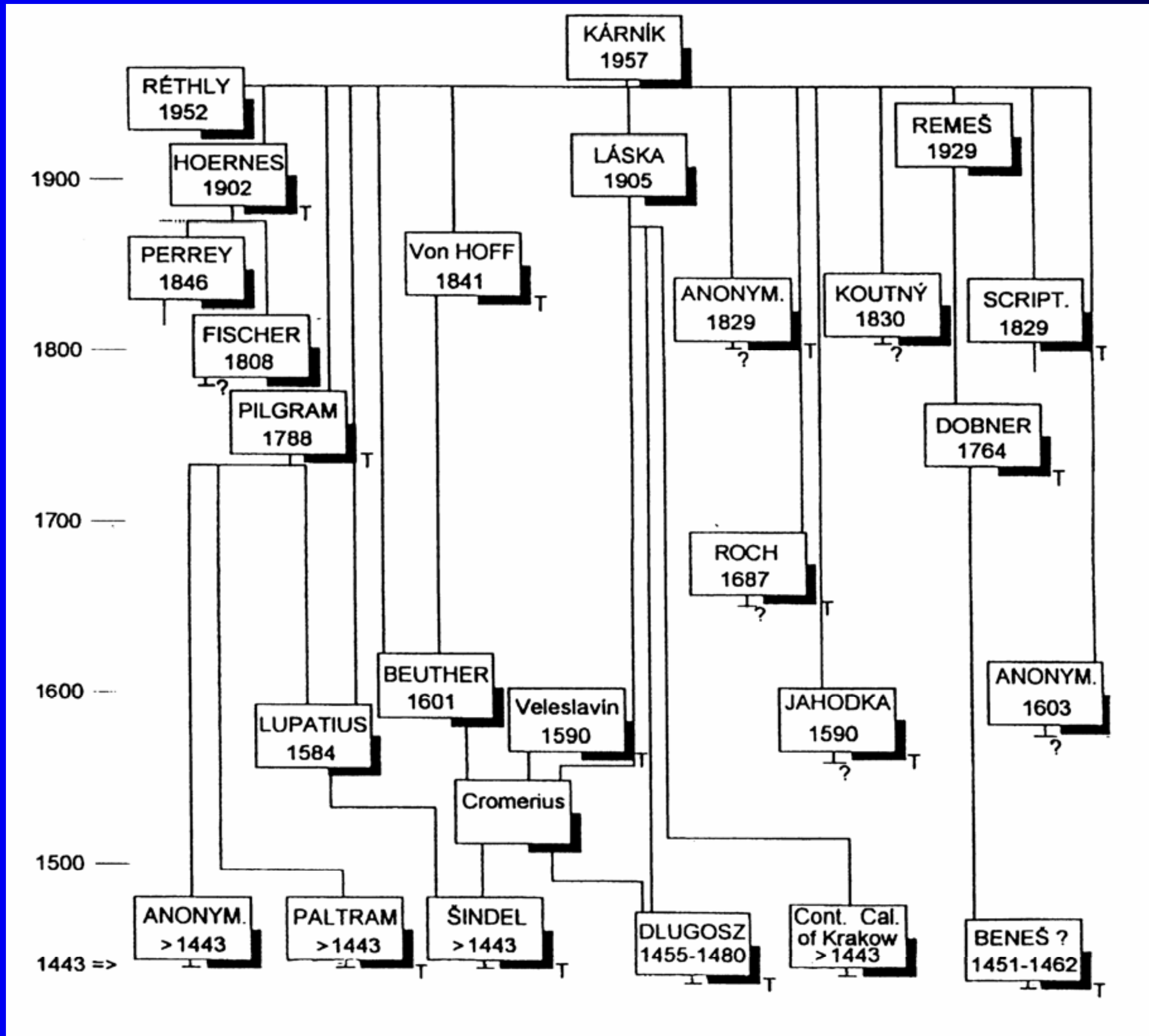


Isoseismal map
by Brouček

In Atlas of
isoseismal maps ...

Seismological database

The June 5, 1443 Central Slovakia earthquake



Seismological database

The June 5, 1443 Central Slovakia earthquake

Prameň	Transkripcia textu
1. Kremnický kódex, (1443-1453).	*Item anno domini mccccxliii quinta die junii, videlicet feria tunc temporis proxime quarta post ascensionem domini sive beati bonifacii etc. Fuit terrae motus magnus, ita quod turres et aedificia reverterunt, duravit per annum succesive. Item anno recoluto die beati vitii iterum magnus, set non ut primus. item anno domini etc. xlv mense aprili die proximo dominico ante georgis martiris, ubi littera dominicalis fuit c in media nocte iterum motus magnus pro ut et viti. item eodem anno in octavia sancti martini confessoris hora precise septima noctis fuit iterum horribile. item anno domini etc. liii die epifaniarum ad noctem videlicet ad diem dominicam hora precise undecima fuit terraemotus satis horrendus et grandis etc.*
2. Mestská kniha Banskej Štiavnice, <1501.	*Item, sequenti anno, feria quinta proxima ante festum Pentecosten, fuit terrae motus magnus, ita ut onia montana, et plura castra, domusque muratae, corruerunt.*
3. Šindel, J., ?. In: Lupatius, P., 1584. Rerum Bohemicarum Emphemeris sive Kalendarium historicum ..., Pragae.	*a.d. mccccxliii v. junii quarta ante pentecostes, hoc, die hora ab artu fere quarta; Hradecii reginae et ibidem circiumcirca; in Moravia quoque Olomoucii et Brunae: item in Austria Viennae per eos districtiatus, praetera in regionibus Ungariae, erat magnus tremor terrae, ita ut multa et magna aedificia ea ipsa concusione quaterentur: turrae alicubi ad instar virgulorum a vento agitaruntur.*
4. Nápis v Levočskom kostole, ?.	*Anno Domini mcdxliii in die V. Juni factus est terrae motus universalis in ruinam multorum aeificorum.*
5. Kalendarz katedry Krakowskiej, ?. In: Monumente Poloniae Historica, Series Nova -t. V. Annales Cracovienses priores cum calendario. Recensuit et annotavit S. Kozlowska-Budkowa, Warszawa, 1978., p. 150-151	*Anno Domini millesimo quadringentesimo quadragesimo tercio sacri Basiliensis concilii anno currente XIII die Mercurii quinta mensis Iunii hora tredecima tremor et motus terre factus fuit magnus et terribilis et in terra tonitru grande ita, ut in civitate Cracowiensi muri omnes facto magno motu, ac si in terram corruere voluissent, maximum fecerunt strepitum et sonum et in multis locis murorum et testudinum scissure magne facte sunt et lapides ac lateres deorsum corruerunt multi. Homines autem propter huiusmodi novum et a seculis in partibus Poloniae inauditum miraculum maximo terrore concussi et stupefacti de domibus ad plateas hinc inde dicurrentes unum alium diligentissime, quidnam factum fuisset, querebant. Sed humano intellectu hec capere non valentes iudicio tandem divine magestatis commiserunt, communiter tamen futuri mali presagium dicebant. Eodem tempore apud Sanctam Katherinam testudo corruit.*
6. Joannis Dlugossi seu Longini canonici Cracoviensi, 1455-1480. Historiae Poloniae, XII Cracoviae 1877, p. 691	*Quinta mensis Iunii generalis tarrae motus praesertim in Poloniae, Hungariae et Bohemiae Regnis et partibus vicinis, adeo validus exortus est, ut turres, aedificiaque murorum corruerent, et singulae domus quantumcunque robustae aut firmae, motu notabili volverentur, fluviorum alvei, aquis in partes utrasque diffugientibus, vacui cernerentur, liquida quaeque salirent, homines pavore subito consternati a sensu et ratione alienarentur. Testudo monasterii Sanctae Catharinae fratrum Beati Augustini in Casimiria, motu illo in terram nocte decidit, et plura alia loca motu terrae ruinata sunt. Intensior tamen motus ipse in Regno Hungariae fuit, ubi et castra quaedam eversa sunt.*
7. Annonymi Vienesis breve chronicon Austriacum, (1453). In: Pez, H., 1721. Scriptores rerum Austriacarum II, col. 550	*a.d. mccccxliii faestus terrae motus feria quarta post erasmi decima die mensi junii*
8. Paltrami Chronicon Austriacum, 1455. In: Pez. H., 1721. Scriptores rerum Austriacarum I, col. 735	*MCCCCXLIII. Venit terraemotus valde magnus, in die S. Bonifacii et cociorum ejus, modicum ante decimam horam, et durat quasi per totam Austriam, et in Ungaria fecit magna dmna, ita quod subvertit castra, et domos et concussit montes in Ungariae ...*
9. Anonym, ?. In: Palacký, F., ed., 1829. Scriptores Rerum Bohemicarum, Tom III.	*380.(m.) Téhož léta (w středu před Sv. Duchem ...) w Uhřích a w Rakúsiech bylo země třesenie weliké, tak že hradby bořili vysoké na skalách, kostely w městech a městečkách, gako zegména hrad w kragi Přewěžském, w městečku Přewěžském kostel se obořil a roztřásl se. Potom Libec hrad we zvolenském kragi wssechen se zbořil kromě jednoho sklepu , a wiece než XXX lidj se zesulo a to brzo po ukazowánj.*
10. Chronicon quod dicitur Benesii Minoritae, ?. In: Dobner, G., 1764-1785. Monumenta historica Bohemiae nusquam antehac edita, Pragae, tom IV., p. 75.	*Anno Domini MCCCCXLIII feria V. mense Junii in die Sancti Bonifacii hora XIII fuit motus terrae in Moravia, per multa loce in Bruno, turres movebantur, in Zabrdowicz turres movebantur sicut virgula retro agitata et cedabant leteres, alicubi ad sanctum Tomam porcio testidunis cecidit in Olomoucz, et per alia loca multa*

Lokalita \ Prameň	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
KREMNICA	H-H									
B. ŠTIAVNICA		H-H								
ĽUBIETOVÁ									H-?	
PRIEVIDZA									H-?	
BOJNICE									H-?	
LEVOČA				H-H						
KRAKÓW					P-P	P-P				
WIEN			A-B				A-A	A-A		
BRNO			B-B							B-B
OLOMOUC			B-B							B-B
H. KRÁLOVÉ			B-B							

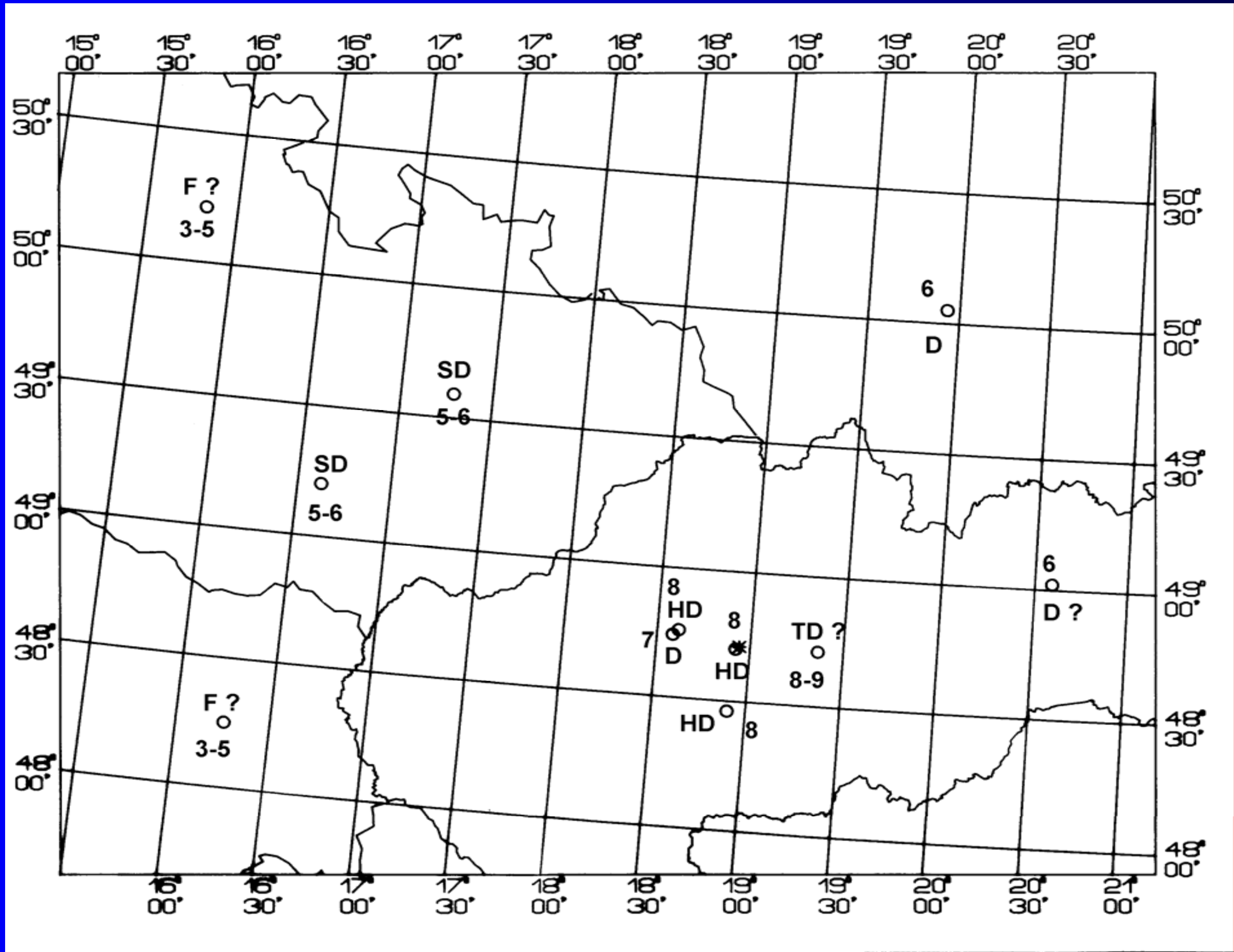
Seismological database

The June 5, 1443 Central Slovakia earthquake

Lokalita \ Prameň	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	I
KREMNICA	HD										8
B. ŠTIAVNICA		HD									>7
ĽUBIETOVÁ									TD?		8-9
PRIEVIDZA									HD		8
BOJNICE									D		7
LEVOČA				D ?							6 ?
KRAKÓW					D	D					6
WIEN			?				F	F			3-5
BRNO			SD							SD	5-6
OLOMOUC			SD							SD	5-6
H. KRÁLOVÉ			F ?								3-5

Seismological database

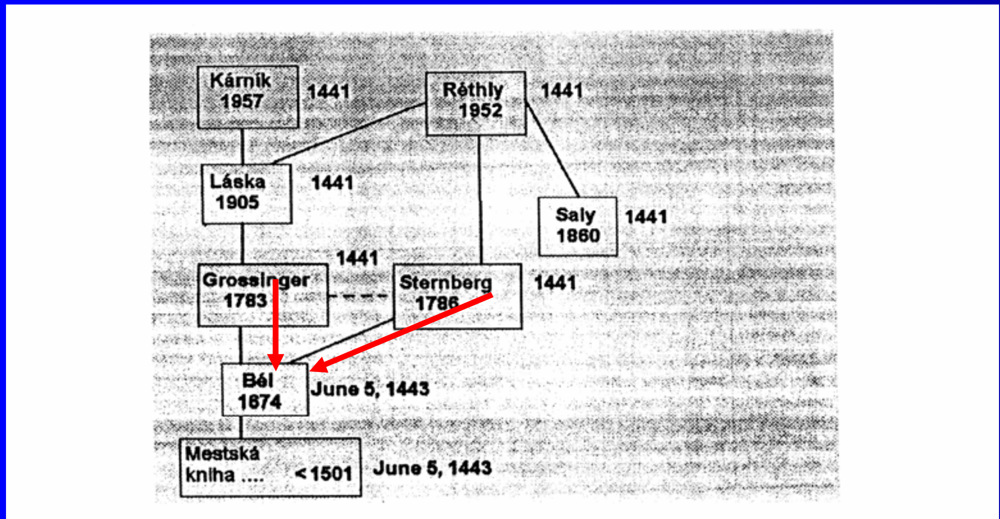
The June 5, 1443 Central Slovakia earthquake



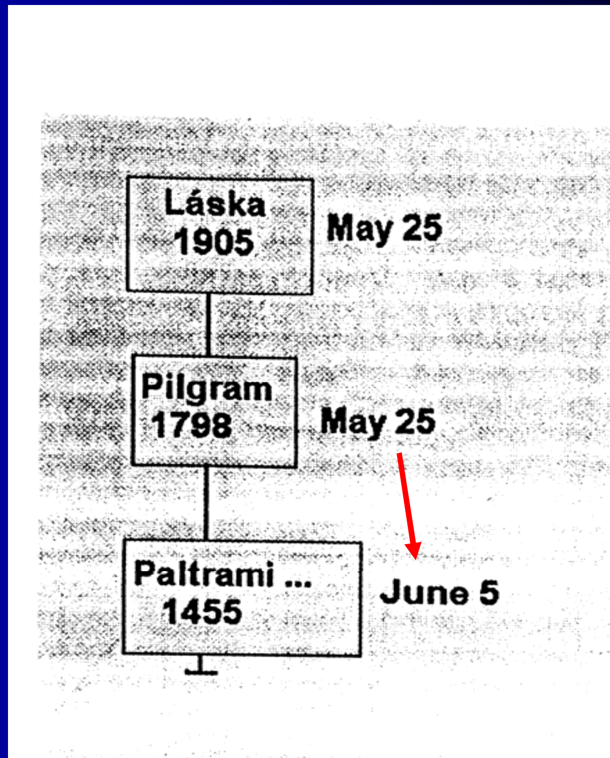
Seismological database

The June 5, 1443 Central Slovakia earthquake

1441



May 25 1443



The 1441 and May 25 1443 earthquakes are fake

Seismological database

The June 5, 1443 Central Slovakia earthquake

The 1441 and May 25, 1443 earthquakes are fake

More than 60 sources were found
for the June 5, 1443 earthquake.
10 of them are the primary sources,
i.e. earthquake contemporary sources.

Sources are missing for the southern part of the shaken area, which includes territory of nowaday's Hungary.

Uncertainty in intensity estimation is higher than previously reported by Brouček.

Seismological database

The June 5, 1443 Central Slovakia earthquake

Uncertainty in epicenter location is high due to absence of the sources in the southern part of the shaken area

Previous estimation of the depth of earthquake hypocenter is unreliable due to low number of input data

Seismological database

The June 28, 1763 Komárno earthquake

Seismological database

The June 28, 1763 Komárno earthquake

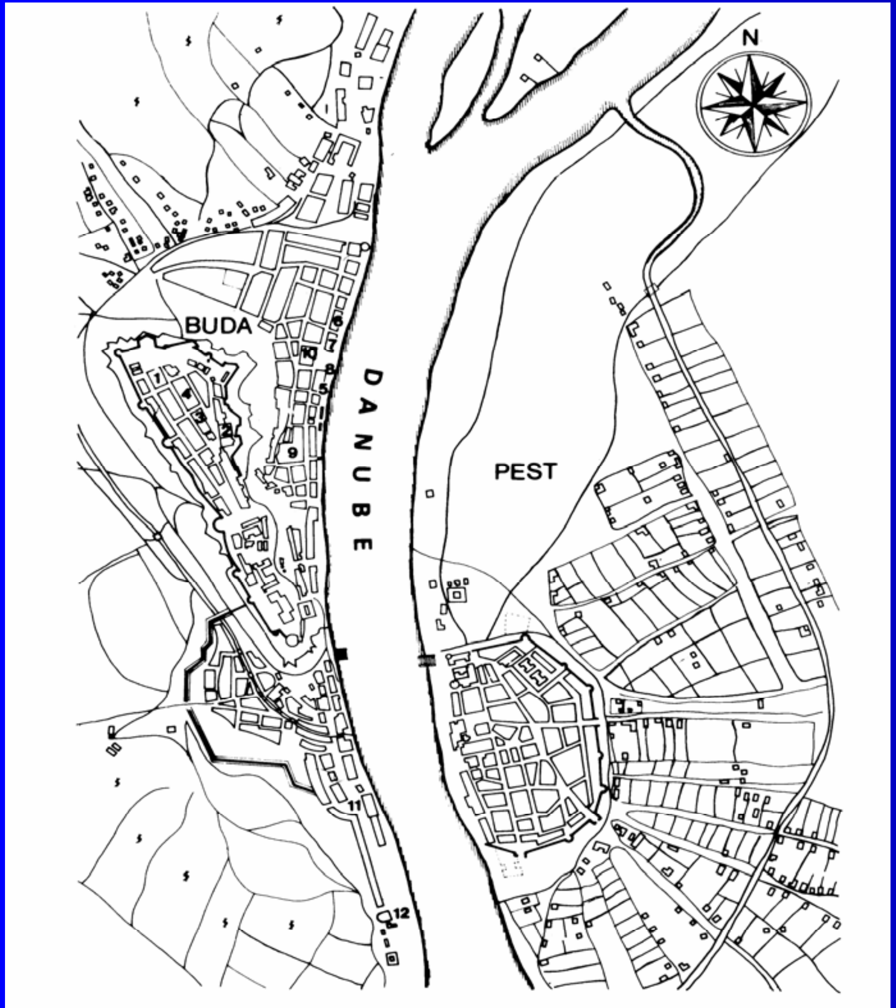


Fig. 3. Building damages at Buda caused by the Komárom earthquake of 28 June, 1763

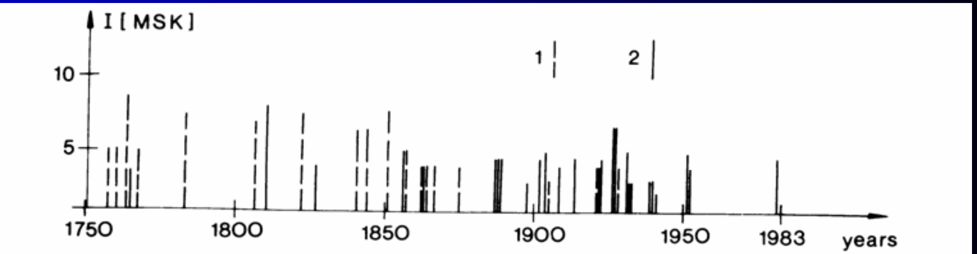
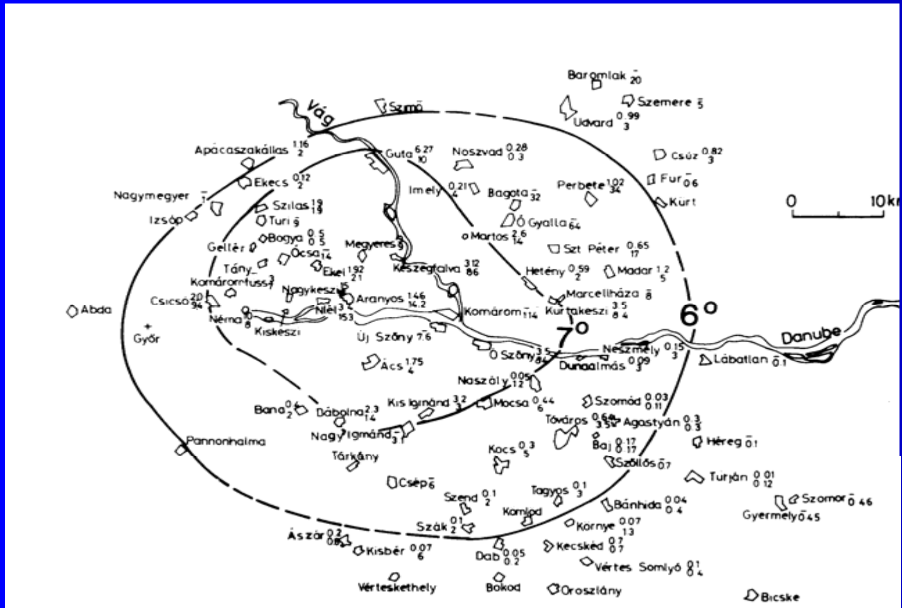
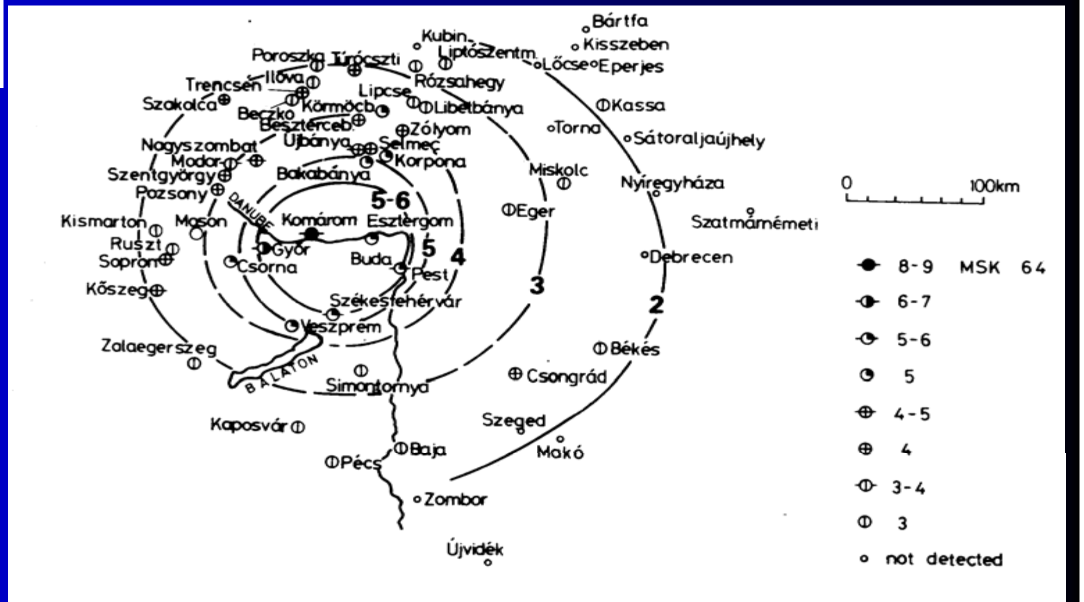


Fig. 7. Main earthquakes from 1763 till the present in the Komárom–Várpalota region
1 — Komárom sources; 2 — other sources

Seismological database

The June 28, 1763 Komárno earthquake





Seismological database

The June 28, 1763 Komárno earthquake

According to the Szeidovitz the earthquake epicenter is localized between Komárno and Iža (E of Komárno).

Later studies try to localize the earthquake W of Komárno.

There is no study available,
which tries to make the localization N of Komárno.

Seismological database

The June 28, 1763 Komárno earthquake

According to the Szeidovitz the epicentral intensity is 8-9^0 MSK-64.

Later studies give the epicentral intensity up to 9^0 MSK-64.

However, those studies do not support their estimation with detailed analysis of the primary sources for the earthquake.

Seismological database

Other earthquakes studied in detail

Apr. 22 1783 Komárno (Szeidovitz, 1987)

Jan 14, 1810 Mór (Stegena & Szeidovitz, 1991)

Jan. 15, 1858 Žilina (Hammerl & Labák, 2001)

Jan. 9, 1906 Dobrá Voda (Labák, unpublished)

Seismological database

Slovakia

Recent earthquakes

- other literature, e.g.
  January 9, 1906 - Réthly (1907)
  March 5, 1930 - Zátopek (1940)

- descriptive catalogues, e.g.
  Kárník et al. (1981)

- bulletins of seismometric observations, e.g. Bulletins of Slovak seismological stations

Seismological database

Merging of the catalogues

Checking whether some earthquake is not included in several parts of the catalogue at the same time (e.g. in the Austrian and Slovak parts)

Checking whether in compiling individual parts of the catalogue for neighboring countries some earthquake was not excluded from all parts of the catalogue

Individual parts of the final catalogue (Slovak, Austrian, etc.) were supplemented with those earthquakes that were missing in the sources used for a given part but were mentioned in the other sources

Excluding fake earthquakes

Seismological database

Final catalogue of macroseismically observed earthquakes

includes all data

for	Slovakia	1443 - 2000
	Hungary	456 - 2000
	Austria	1267 - 2000
	Czech Rep.	1358 - 2000
	Poland	1259 - 2000

The catalogue also includes uncertainties
in estimation of epicentral parameters

Magnitudes are computed from regional relationships
between M, I_0 and h

Sources of the parameters are given for each earthquake

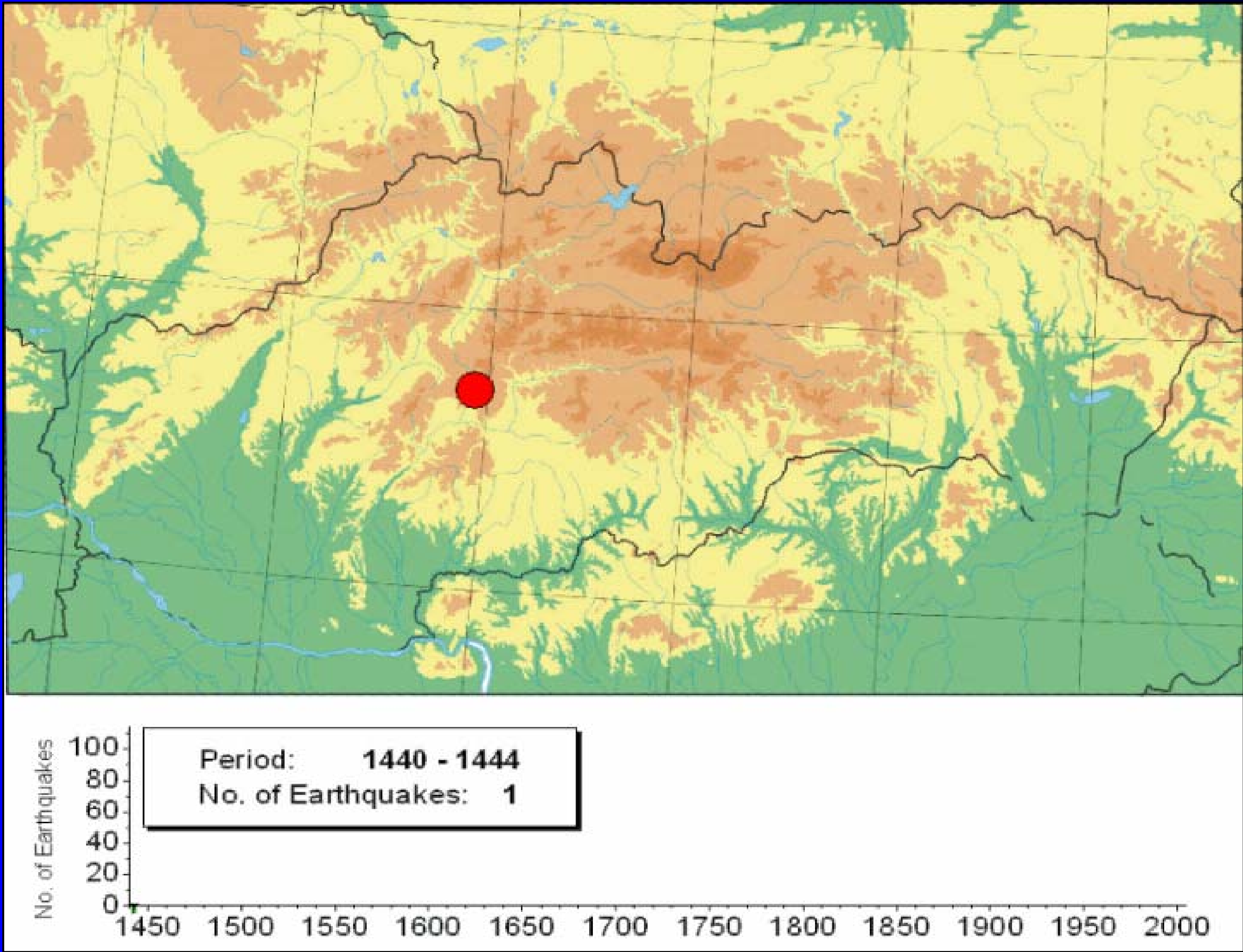
All available isoseismal maps were also collected

Seismological database

Final catalogue of macroseismically observed earthquakes

- **epicenter location - not better than +/- 10 km**
- **accuracy of the I_0 - not better than +/- 0.5 MSK**
- **data covers not more than last 500 - 700 years**

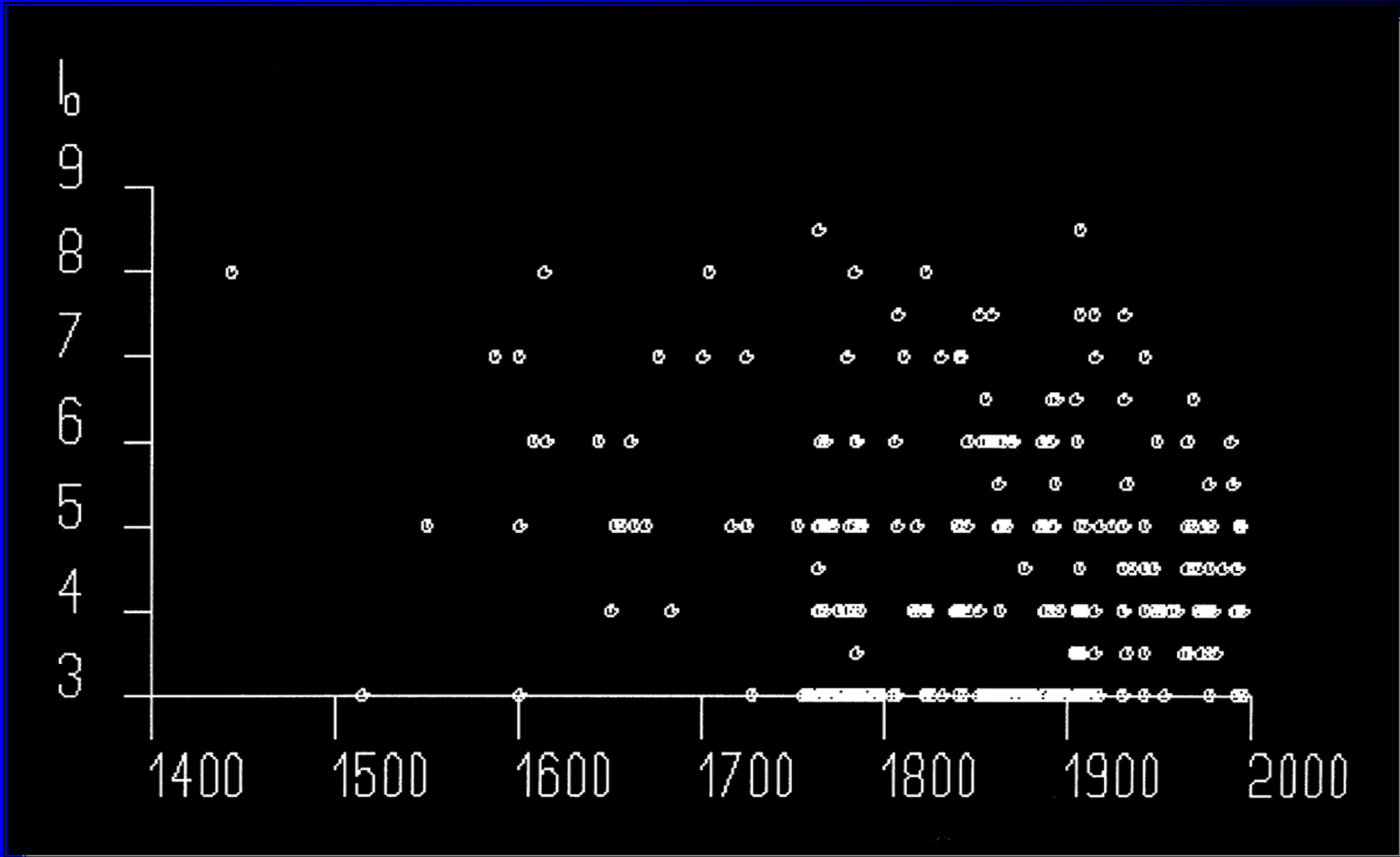
Data on historical earthquakes represents a crucial part of the seismological database in the EMO and EBO far region



Period: 1440 - 1444
No. of Earthquakes: 1
No. of Earthquakes
100
80
60
40
20
0
1450 1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000

Seismological database

Earthquake history of Slovakia



Seismological database

Data on instrumentally recorded earthquakes

compiled for the Slovak territory

BCIS bulletins	1956 -1967
ISC bulletins	1967 -1992
Bulletins of Czechoslovak seismic stations	1956 -1988
Bulletins of Slovak seismological stations	1967 -1990
So far unpublished data from questionnaires	1991 - 2000

Seismological database

Data on instrumentally recorded earthquakes

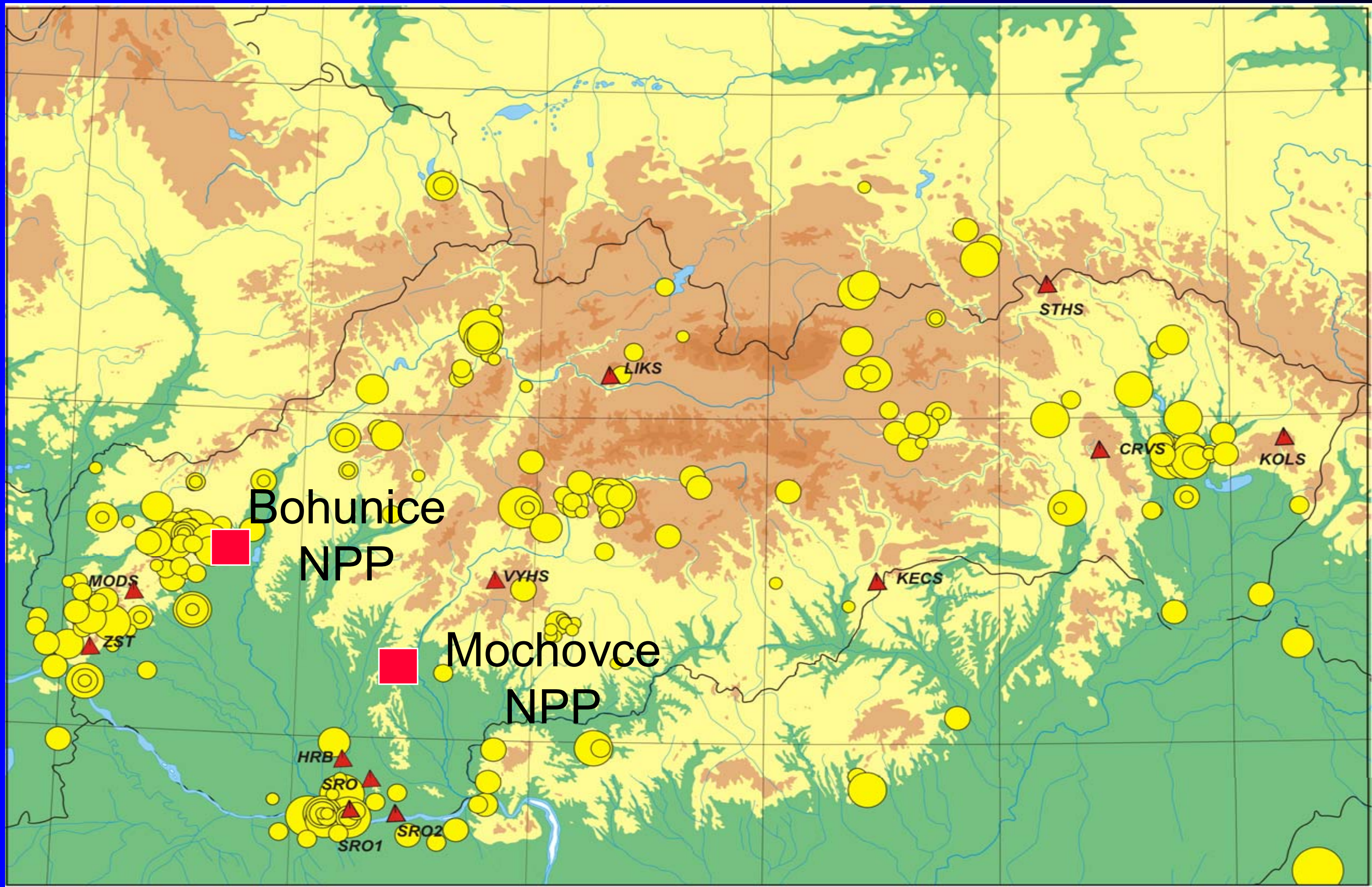
Data on instrumentally recorded earthquakes is available only for relatively small number of earthquakes

Until the middle of 60s - poor quality of the data; instrumental localizations are not better than macroseismic ones for this period

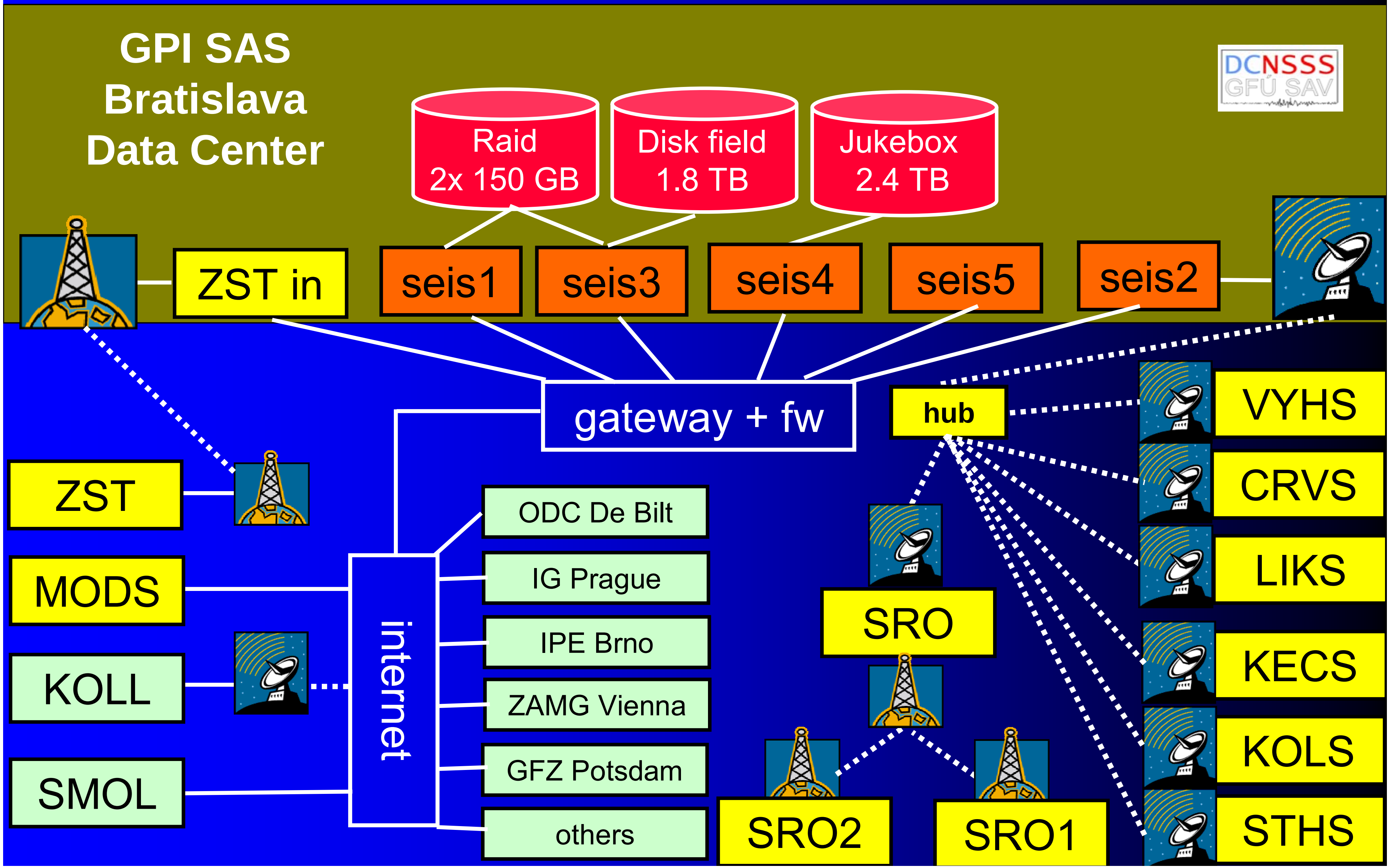
Data on instrumentally recorded earthquakes has only complementary character compared to data on macroseismically observed earthquakes in the far region

Seismological database

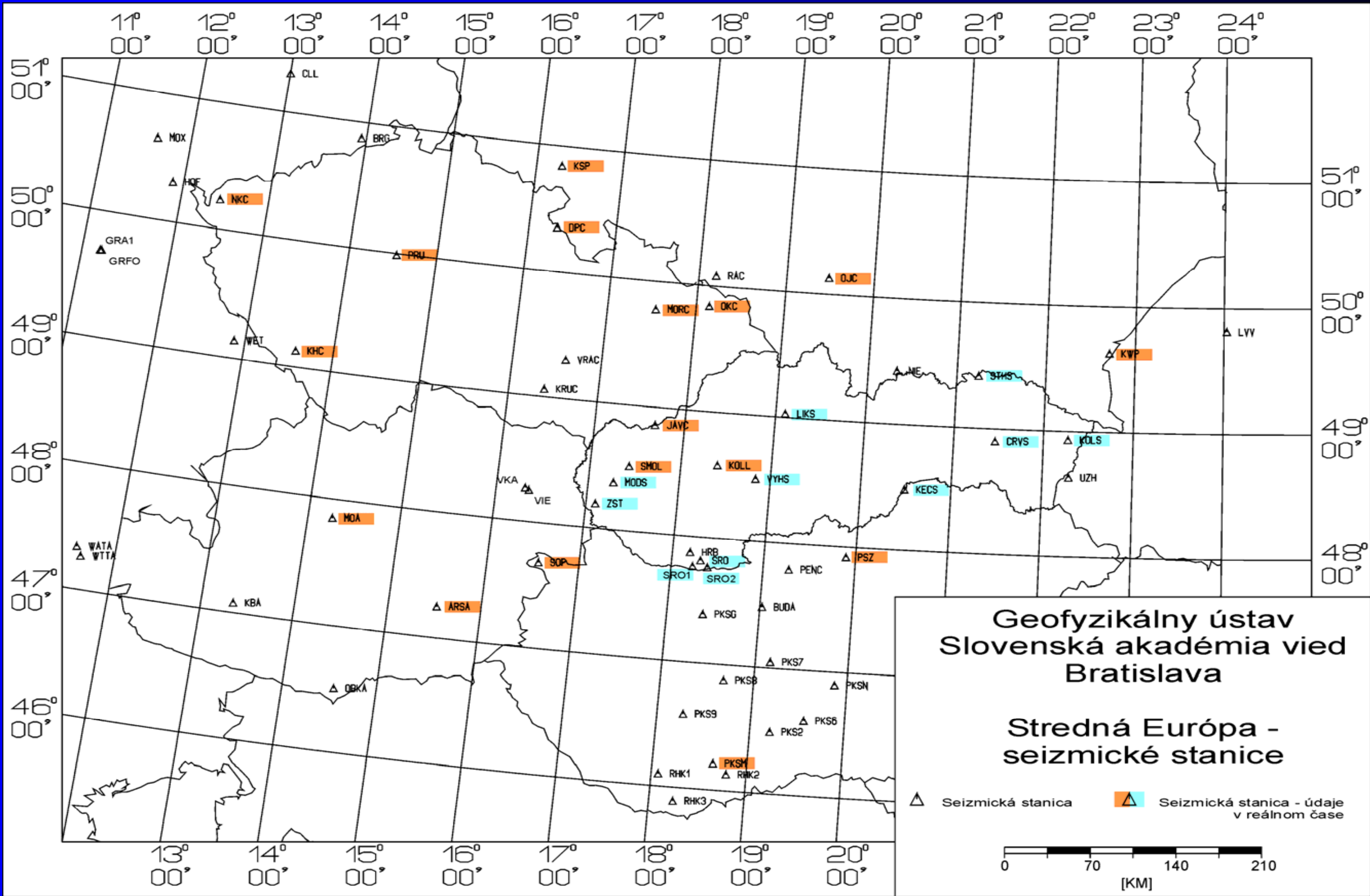
Slovak National Network of Seismic Stations



Virtual Network of Seismic Stations



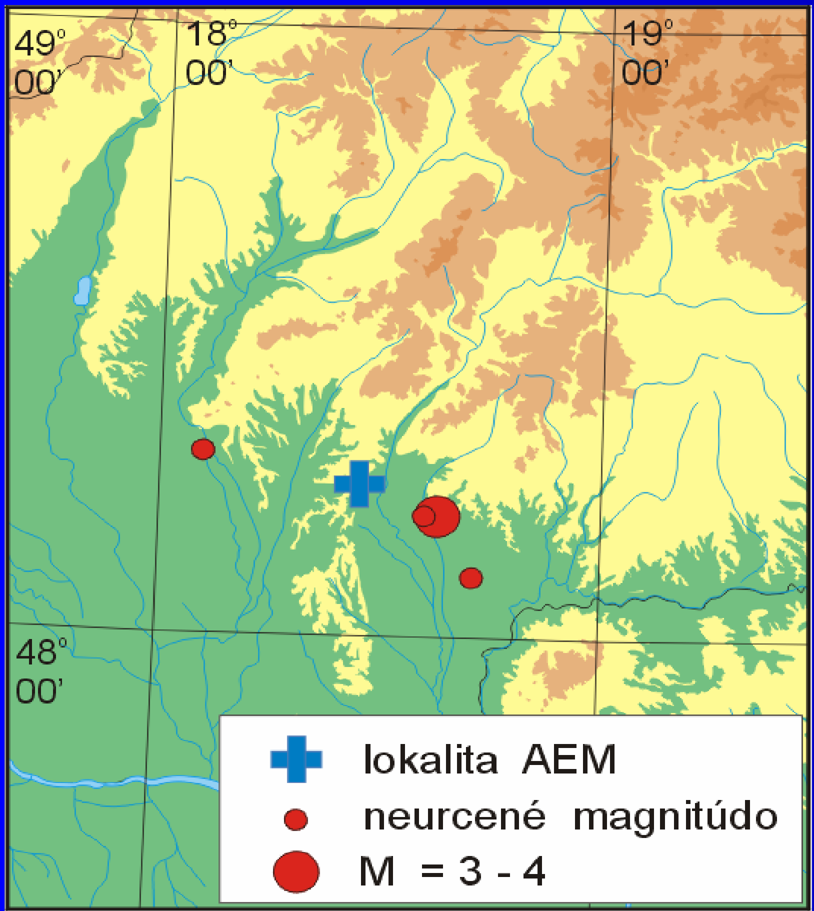
Virtuual network of seismic stations



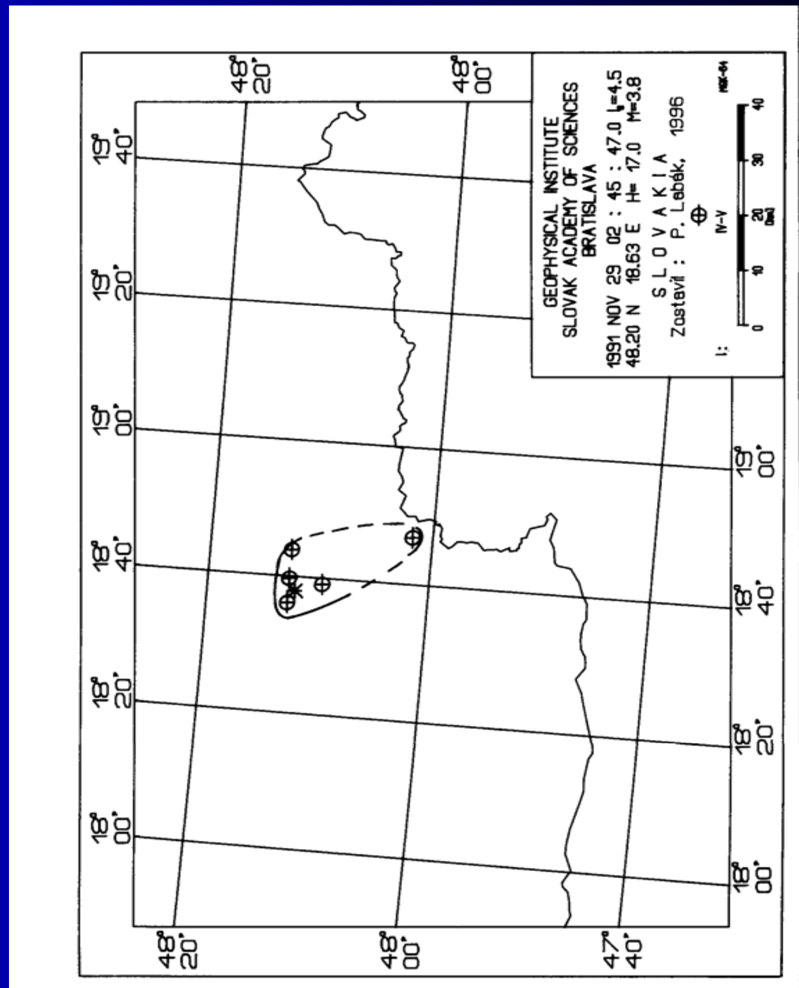
Seismological database

Activity in Mochovce NPP near region

1950 - 1997

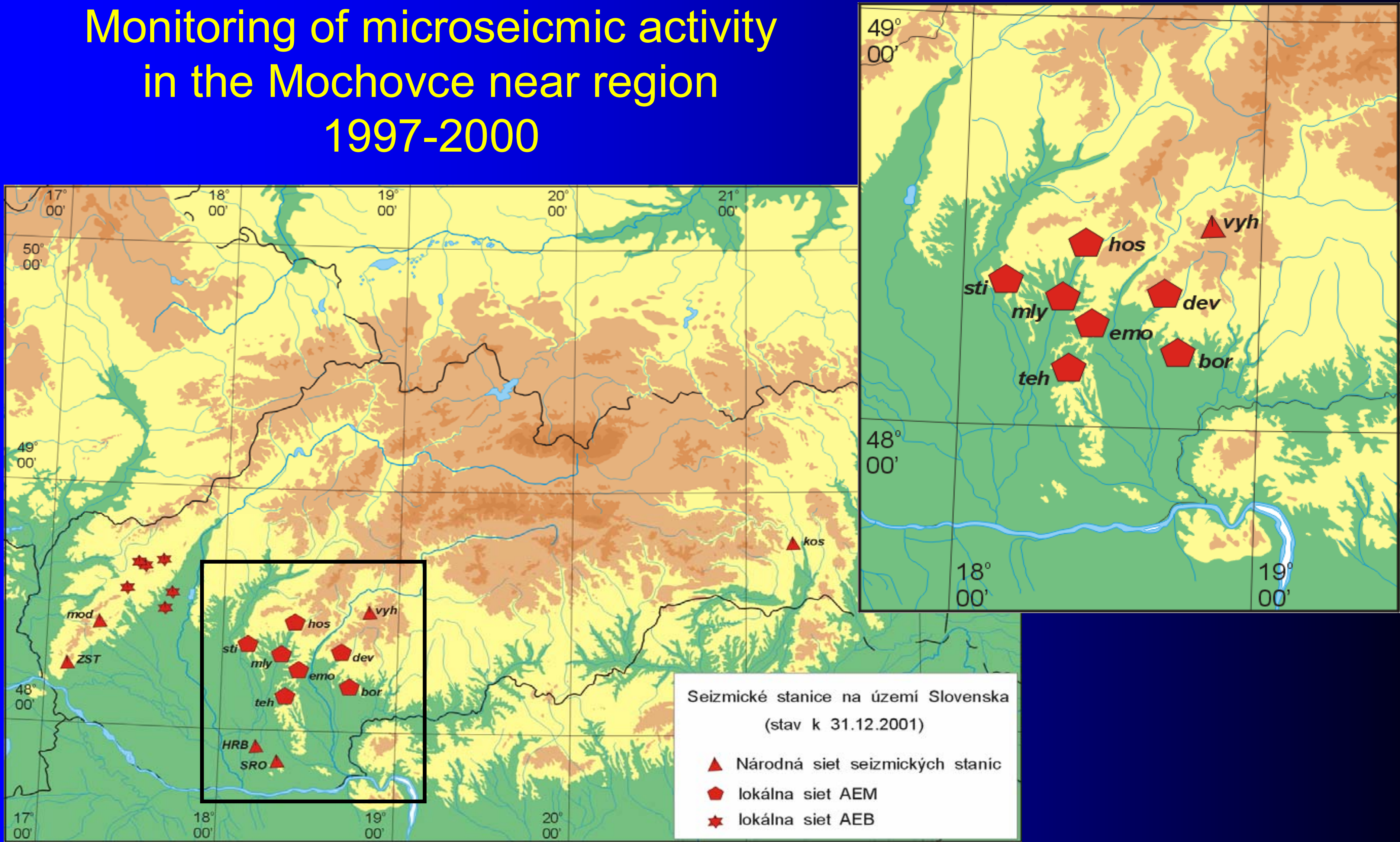


28.11.1990



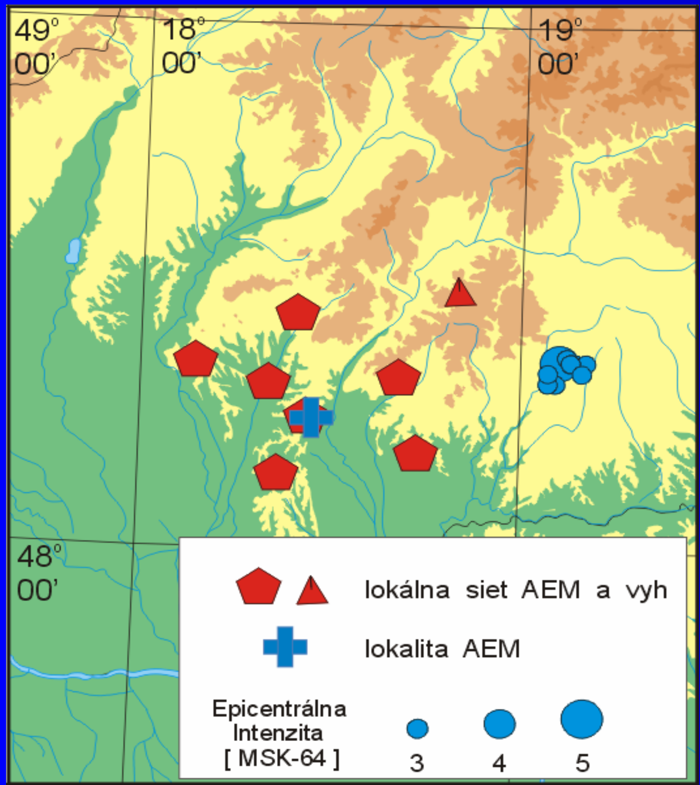
Seismological database

Monitoring of microseicmic activity
in the Mochovce near region
1997-2000

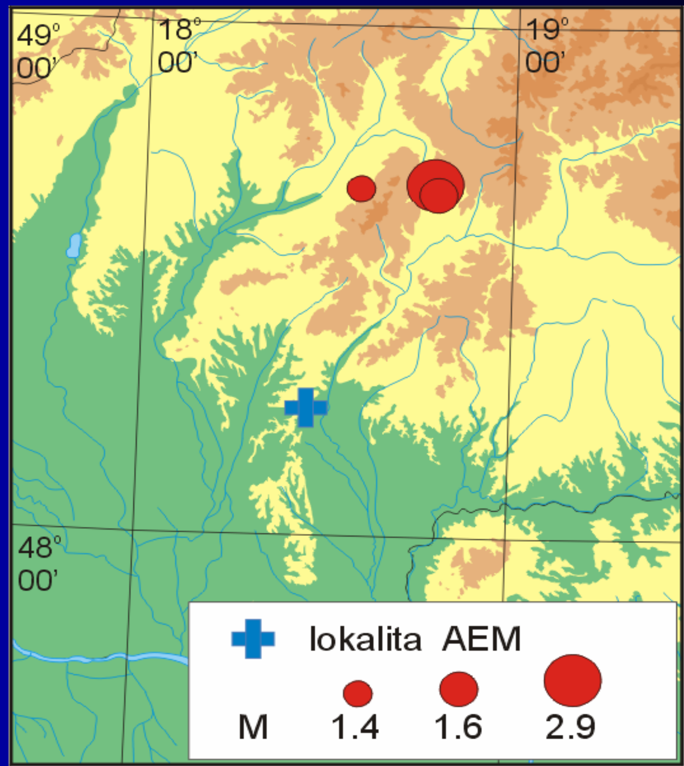


Seismological database

Krupina
1999

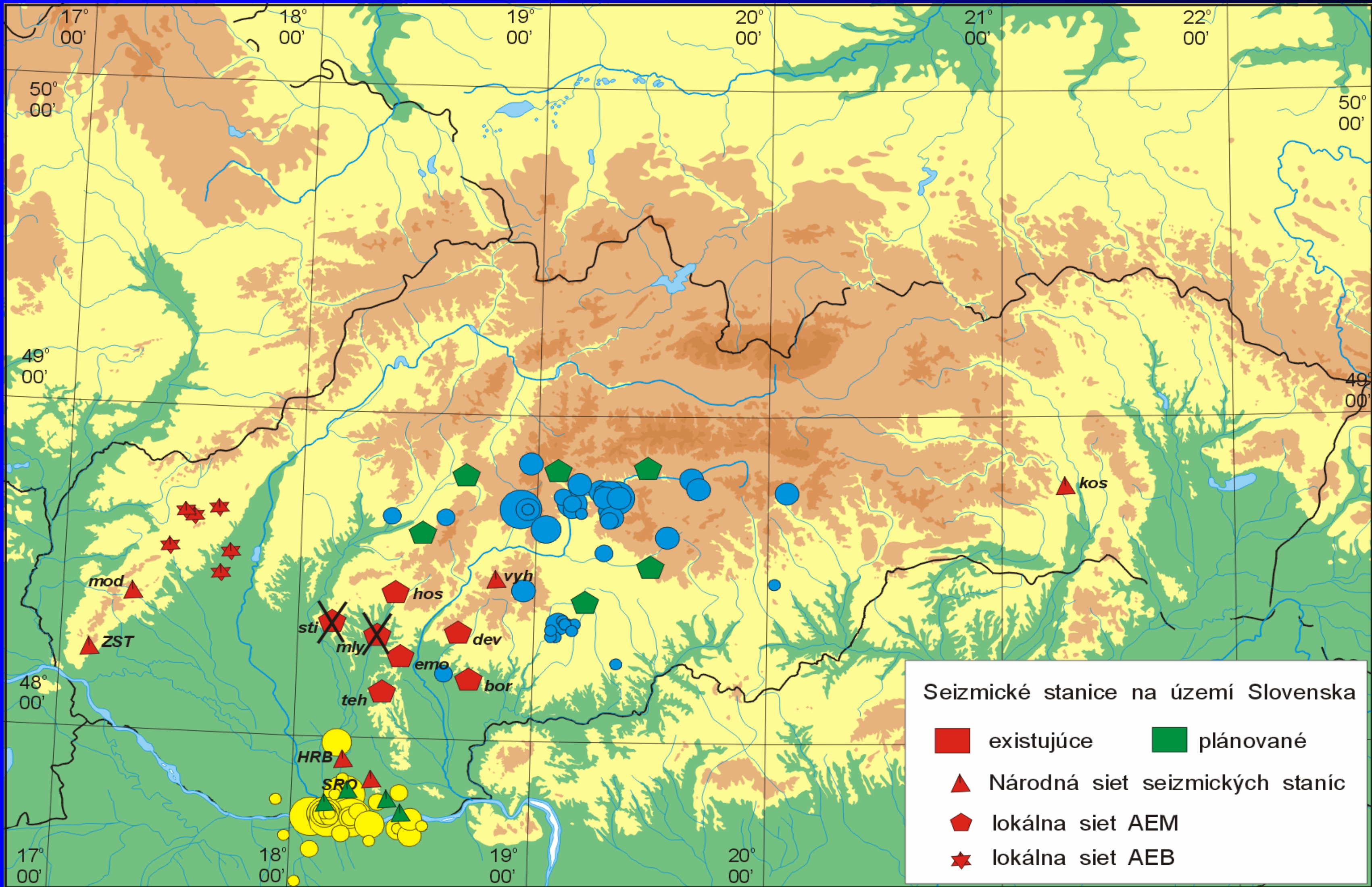


Prievidza
1997-2000



Seismological database

Re-configuration of the EMO local network



Seismological database

Existing configuration of the Mochovce NPP local network allowed registering the microseismic activity of the near region

Results of the monitoring indicate low activity in the Mochovce NPP near region for the period 1997-2001

However, two active source zones exist in the vicinity of the Mochovce NPP near region, the Komárno source zone and the Central Slovakia source zone

Data on microseismic activity in both source zones are still missing

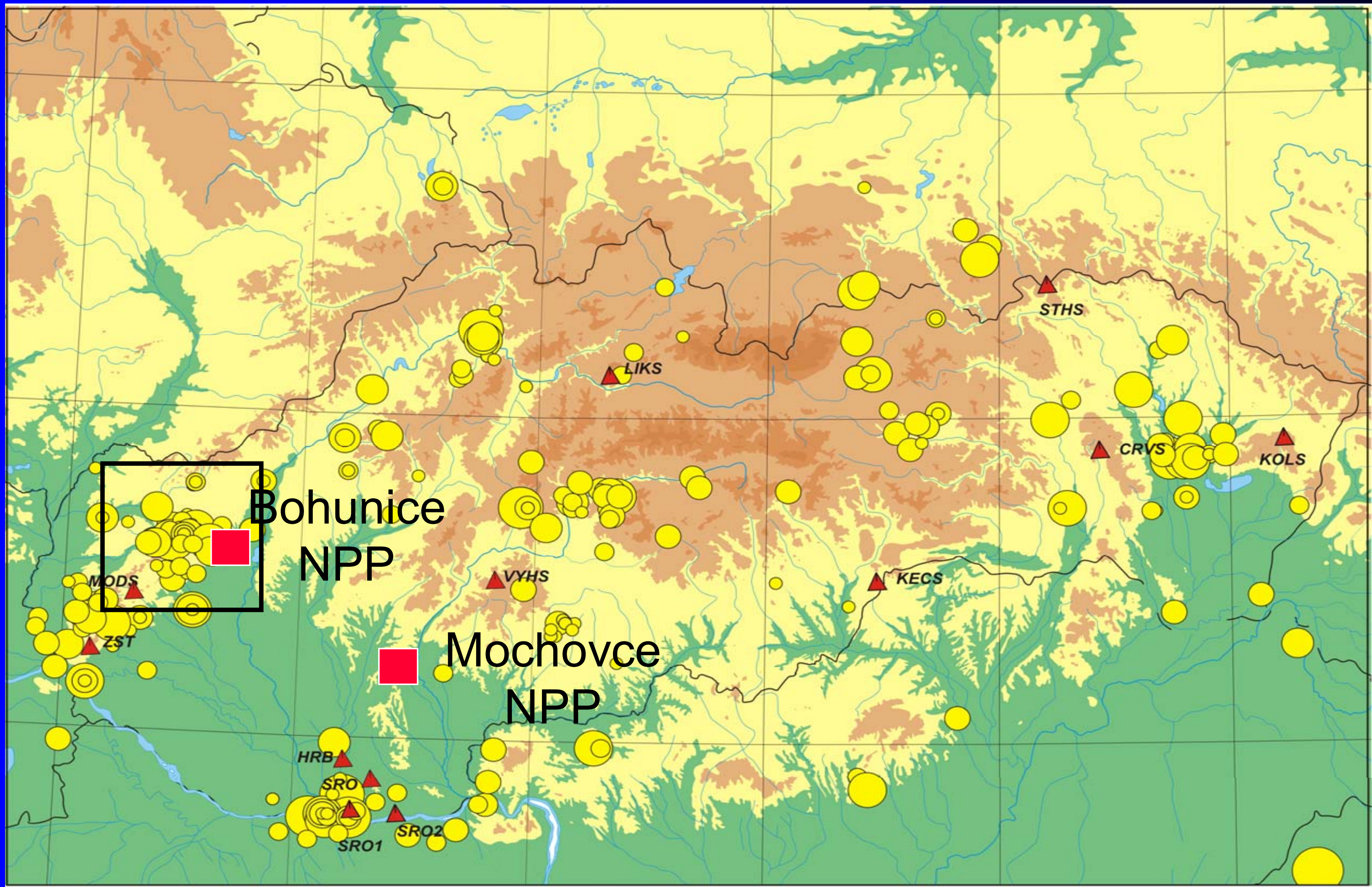
Seismological database

Therefore, we suggested
reconfiguring and enlarging
the Mochovce NPP local network in the way that allows
monitoring of the microearthquake activity
in the Central Slovakia source zone

The configurations of the new National network
and the new Mochovce NPP local network allow
monitoring of the microseismic activity
in the Central Slovakia and Komárno source zones,
and in the Mochovce NPP near region

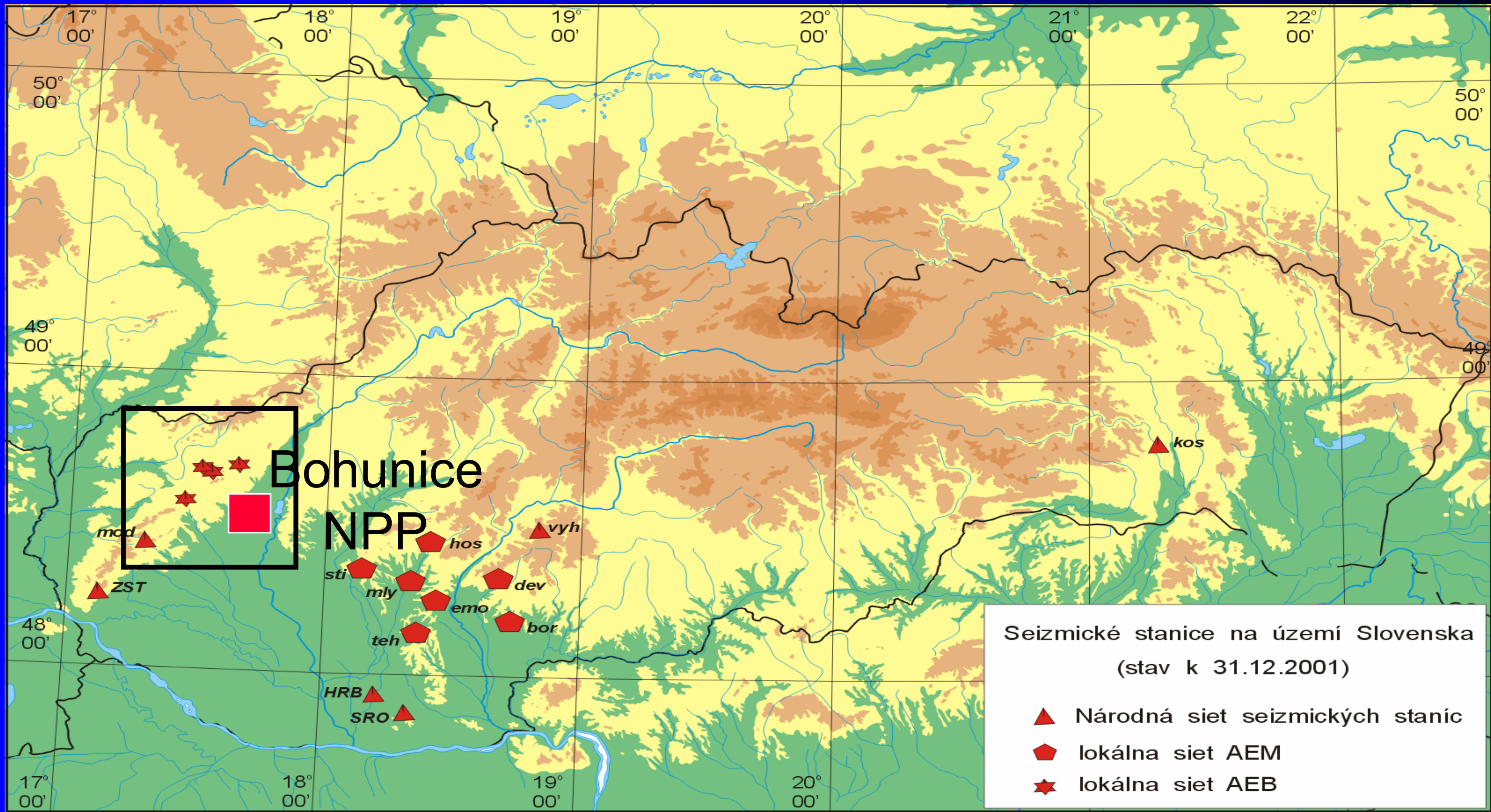
Seismological database

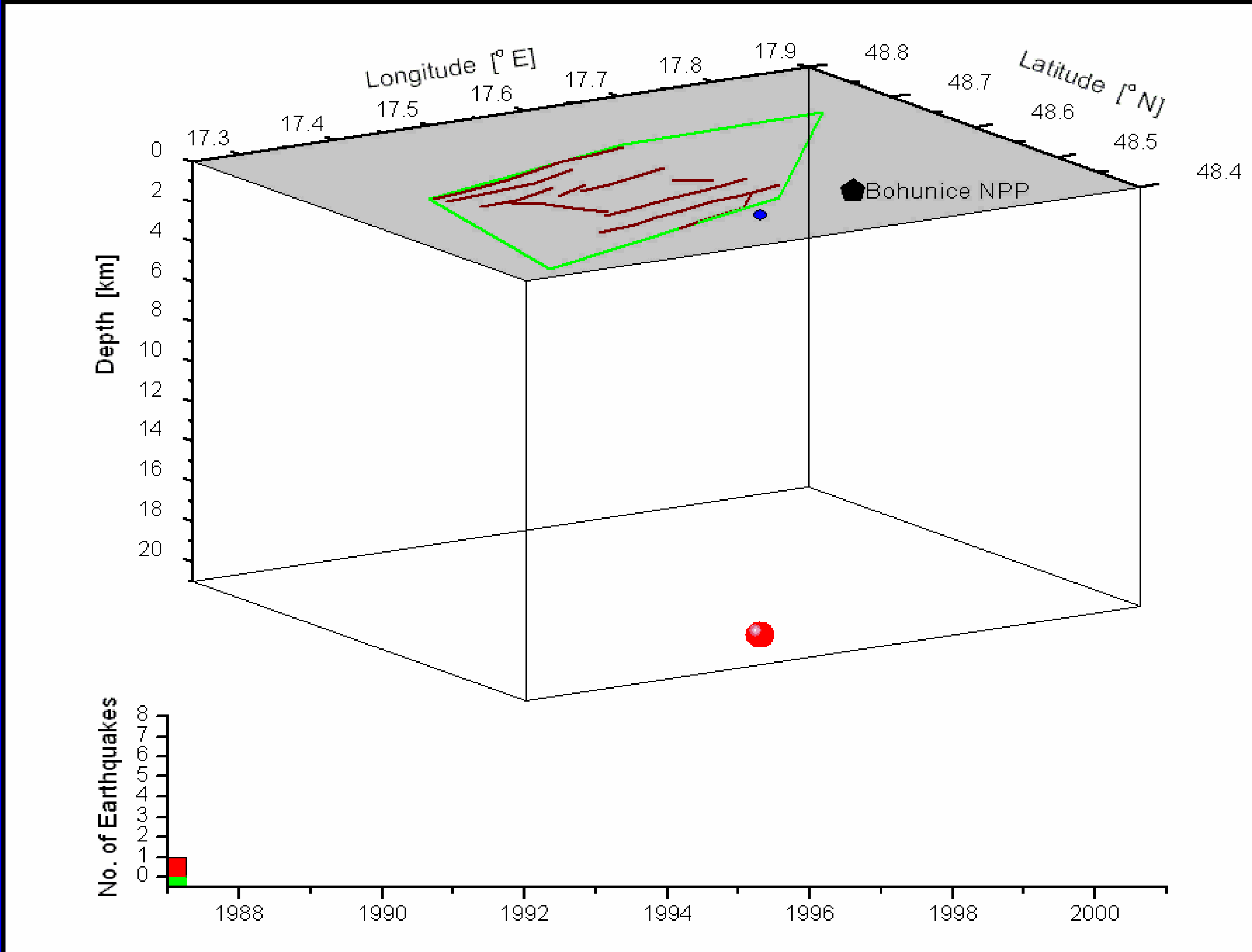
Slovak National Network of Seismic Stations and Bohunice NPP



Seismological database

Monitoring of microseicmic activity
in the Bohunice near region 1987-2000

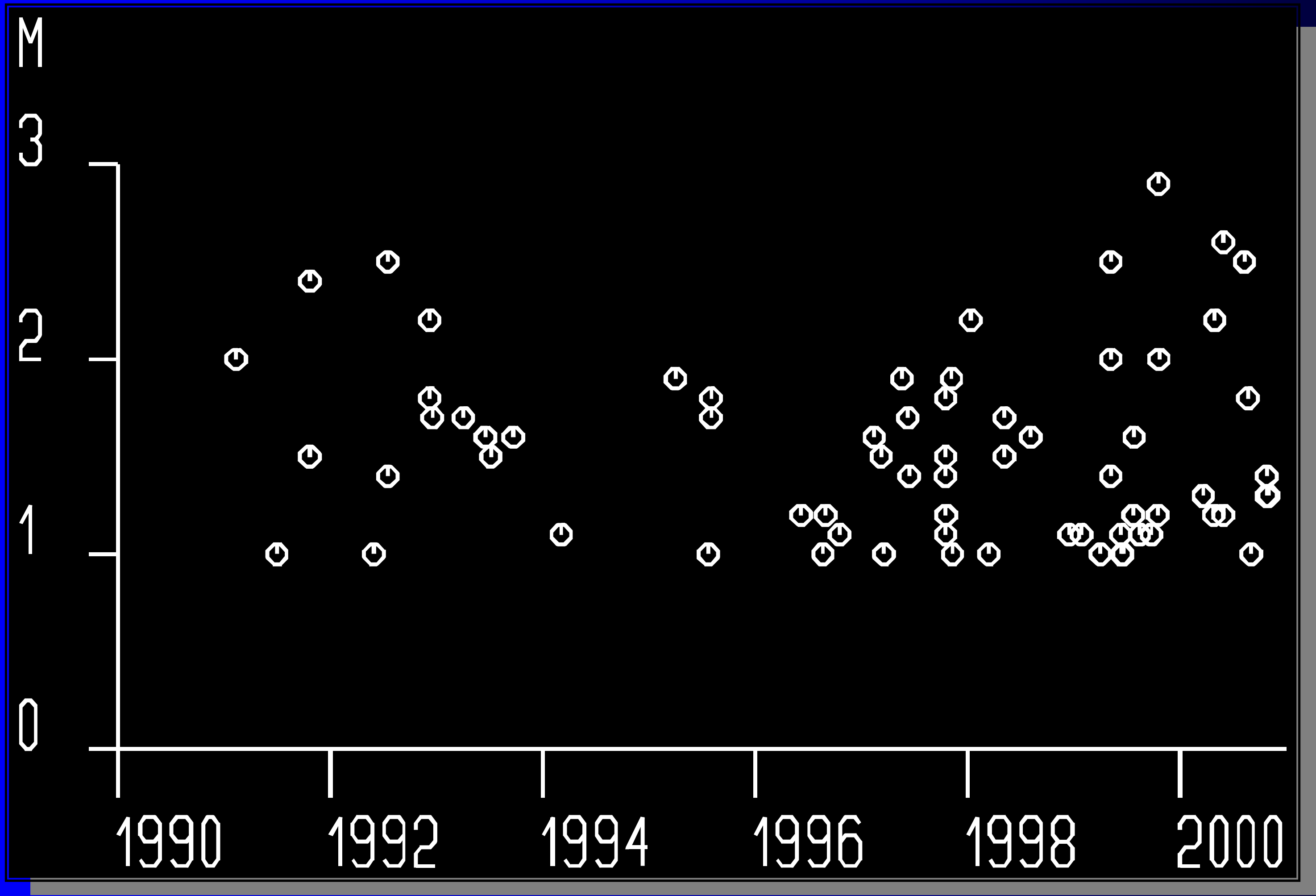




Longitude [° E]
17.3
17.4
17.5
17.6
17.7
17.8
17.9
Latitude [° N]
48.8
48.7
48.6
48.5
48.4
Depth [km]
0
2
4
6
8
10
12
14
16
18
20
Bohunice NPP
No. of Earthquakes
8
7
6
5
4
3
2
1
0
1988
1990
1992
1994
1996
1998
2000

Seismological database

Microseismic activity - Dobrá Voda



Seismological database

Summary

Various types of data
- historical, recent
- macroseismic, seismometric

Various methods of data analysis
- historical seismology
- recent macroseismic
- methods of analysis of instrumental data from regional and local networks

Therefore, the database is very heterogenenous.
This is reflected mainly in uncertainty of earthquake data and it influences construction of seismotectonic model

Seismotectonic model

- **Determination of source zones in the far region**
- **Determination of source zones in the near region**
- **Choice of the minimum magnitude**
- **Determination of the maximum magnitude in the far region**
- **Determination of the maximum magnitude in the near region**
- **Determination of the magnitude-frequency relationships**

Seismotectonic model

Source zones (areal source zones, fault zones)

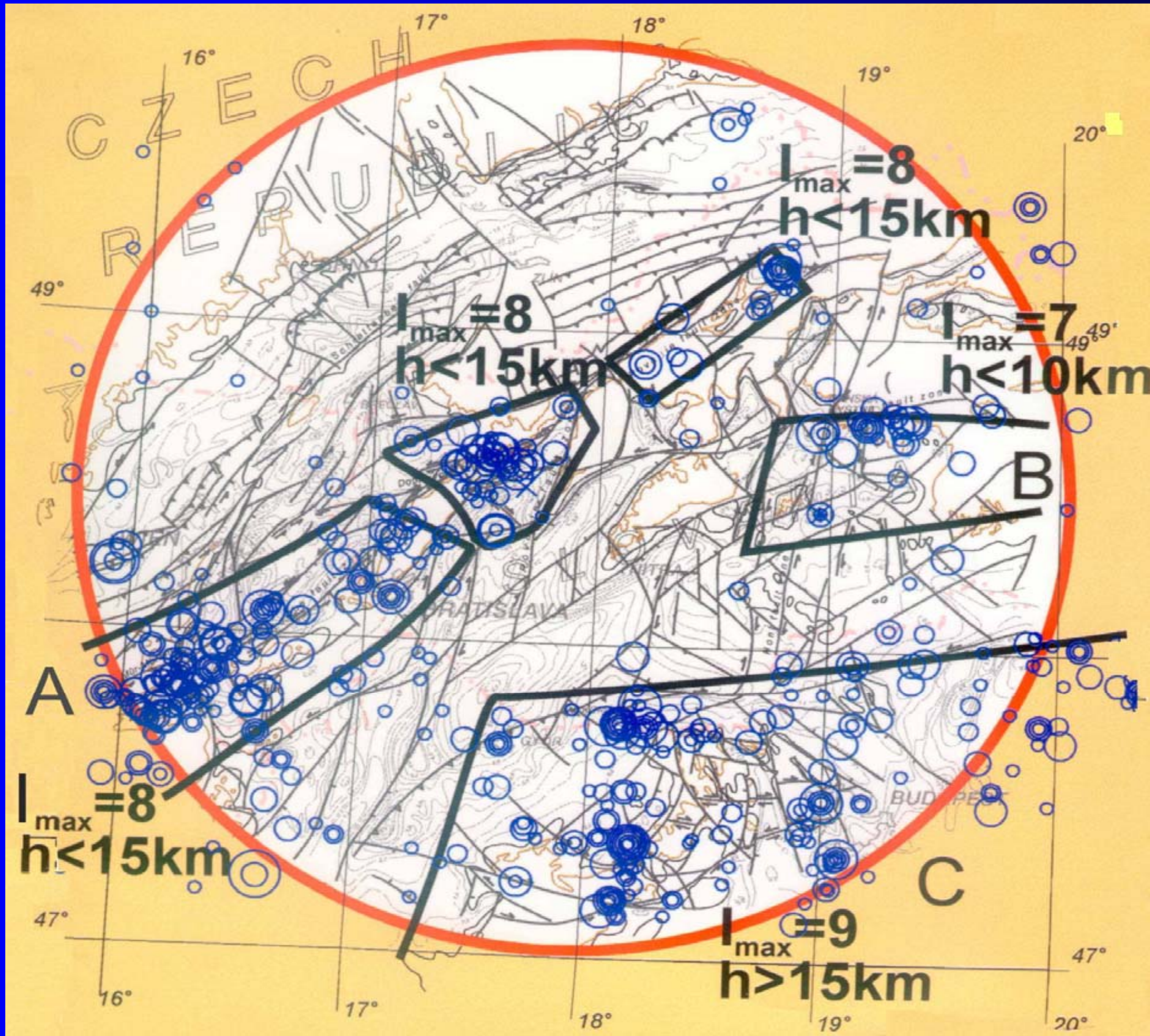
Far region

- areal source zones due to large uncertainty in location of the macroseismically observed earthquakes
- geological vs. seismological data -> alternative models

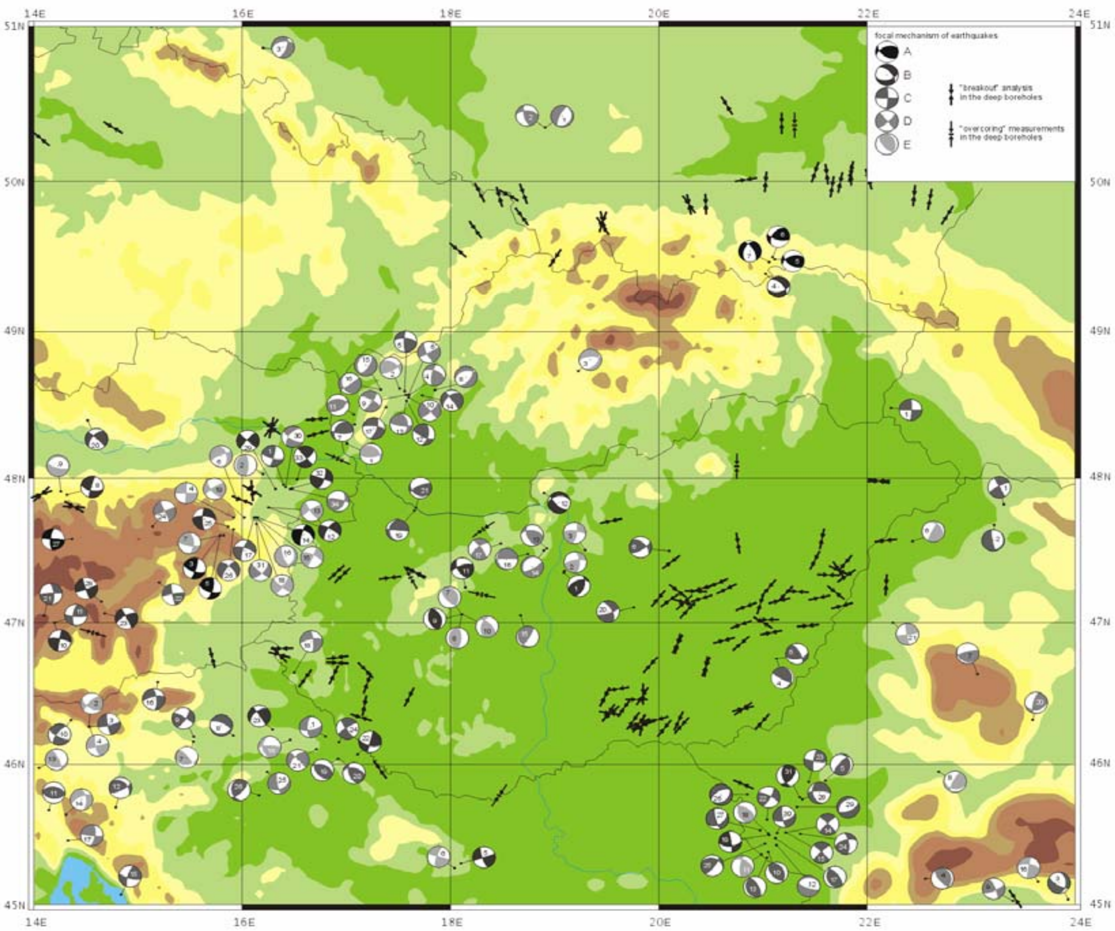
Near region

- faults because of higher resolution of geological and seismological data
- alternative fault models – uncertainty in the available data

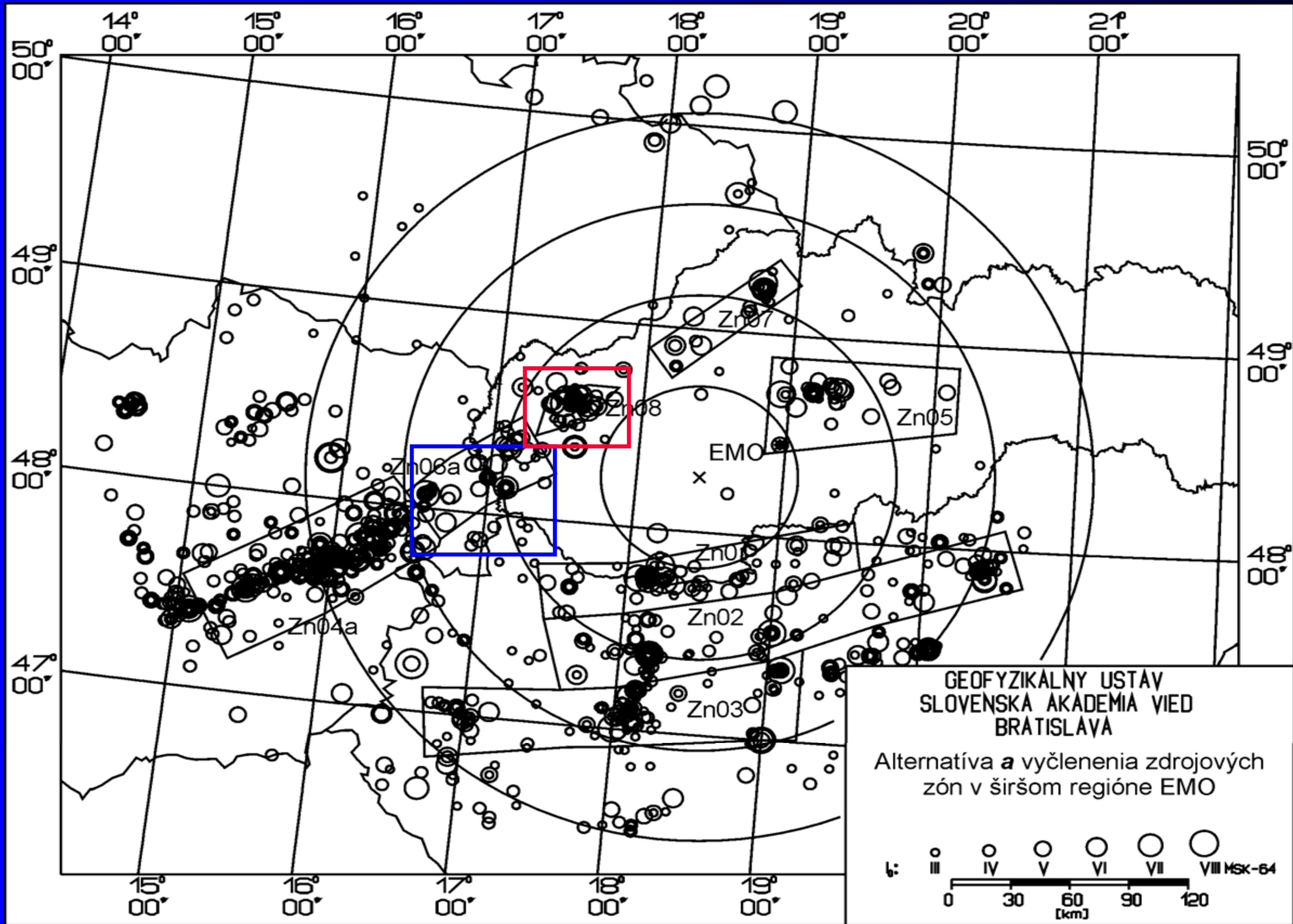
Seismotectonic model



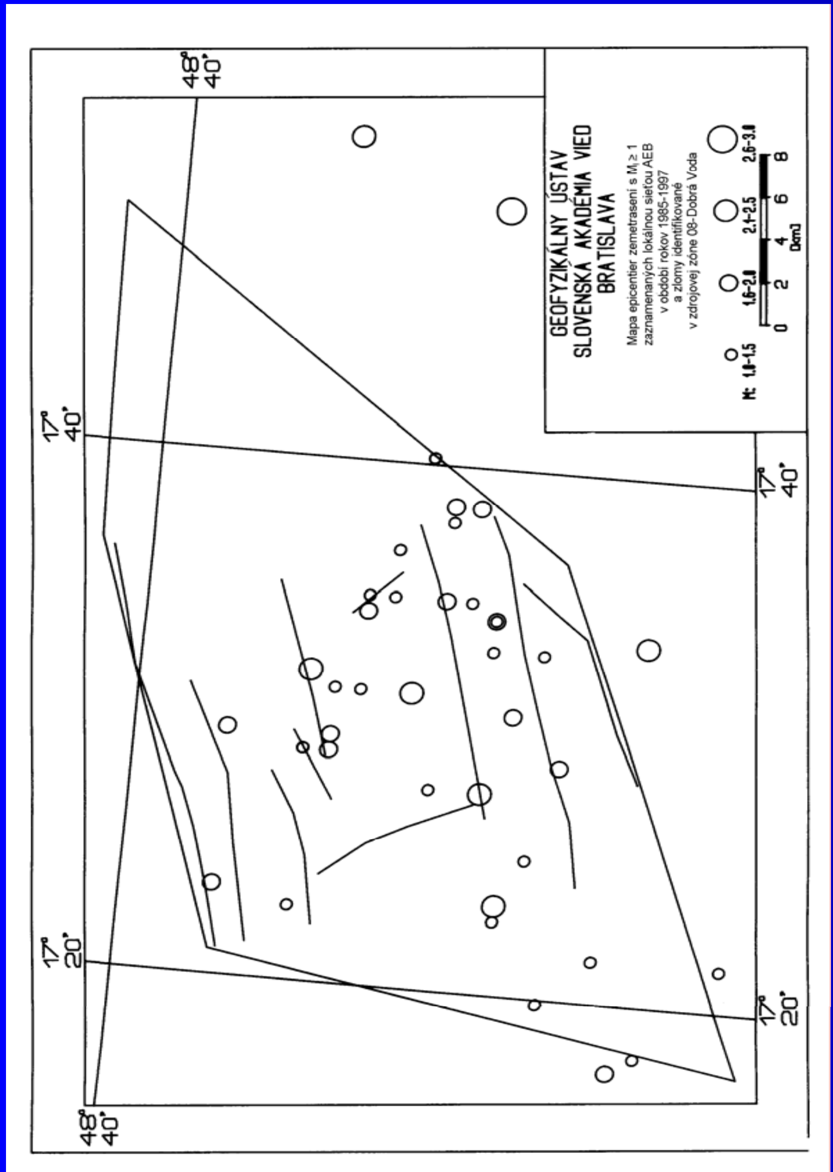
Seismotectonic model

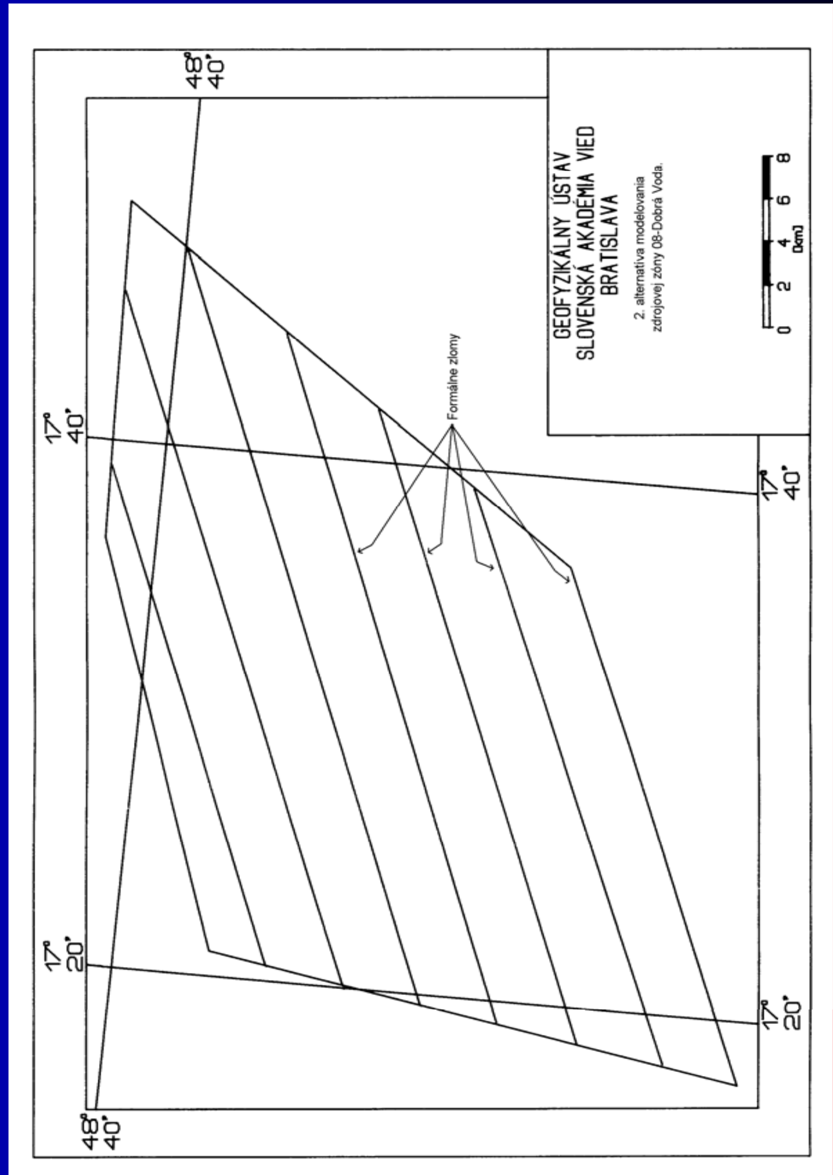


Seismotectonic model

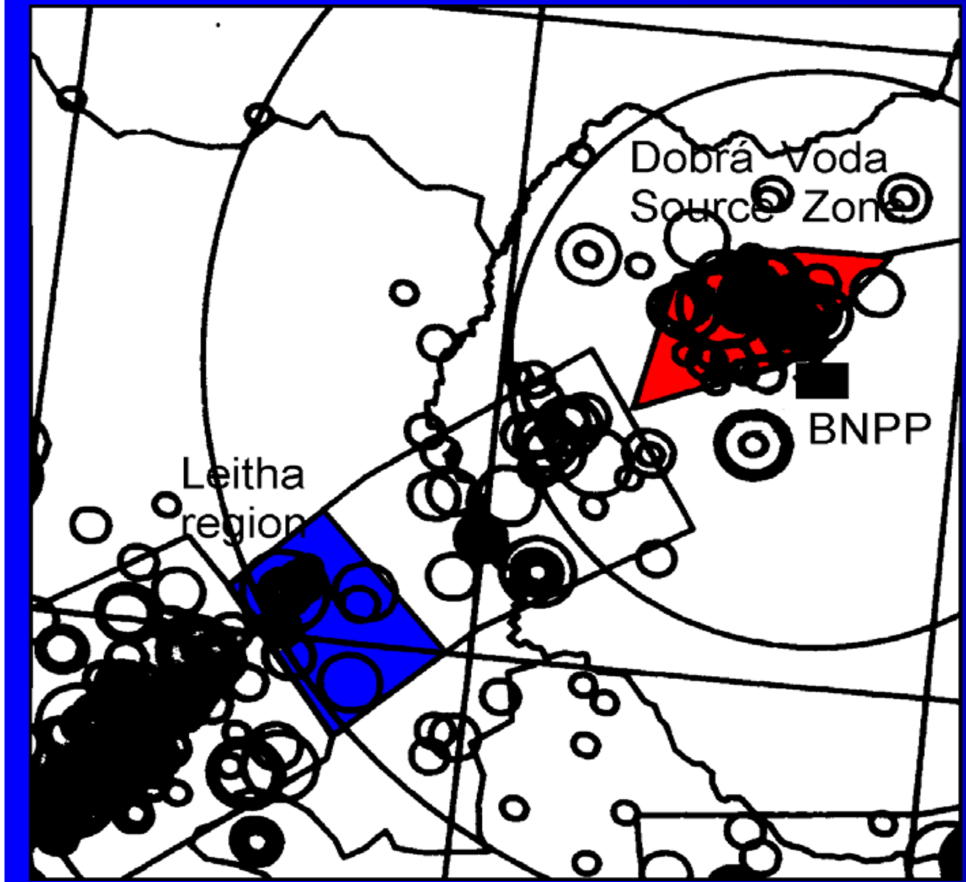


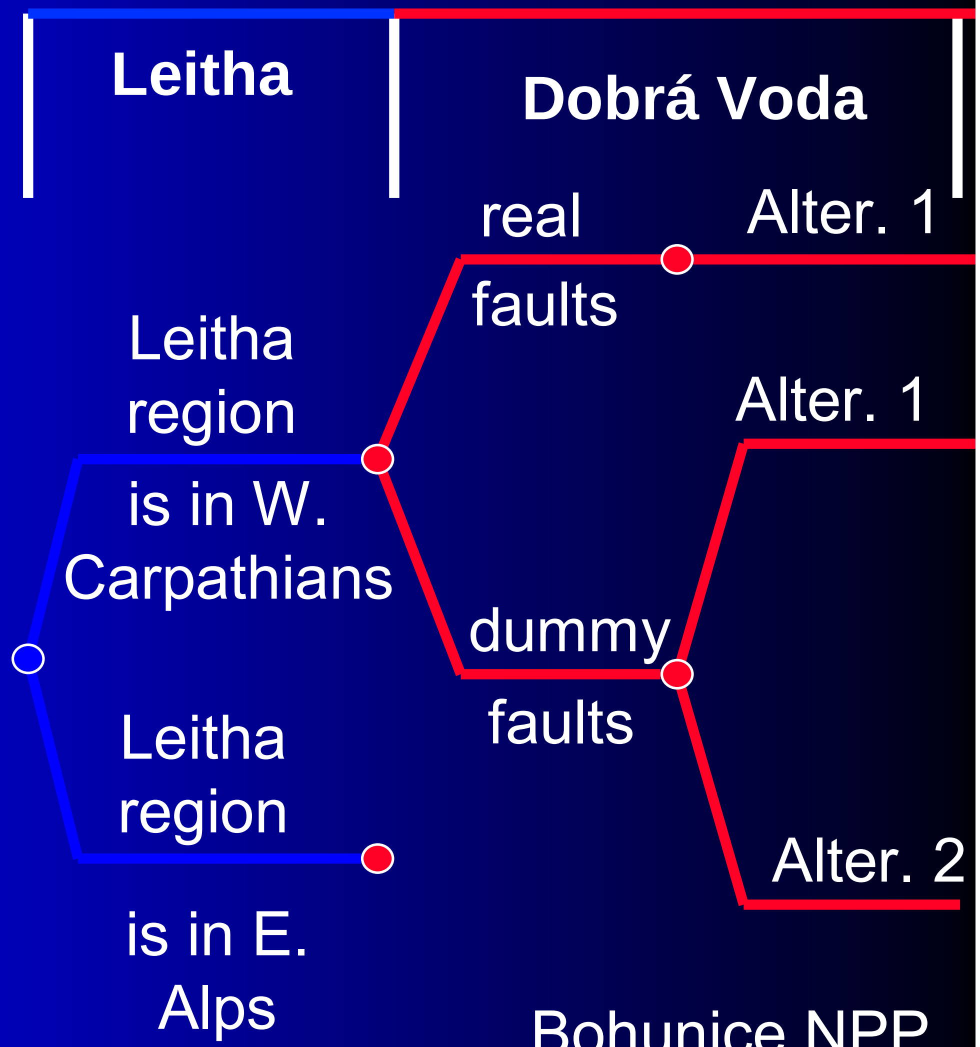
Seismotectonic model





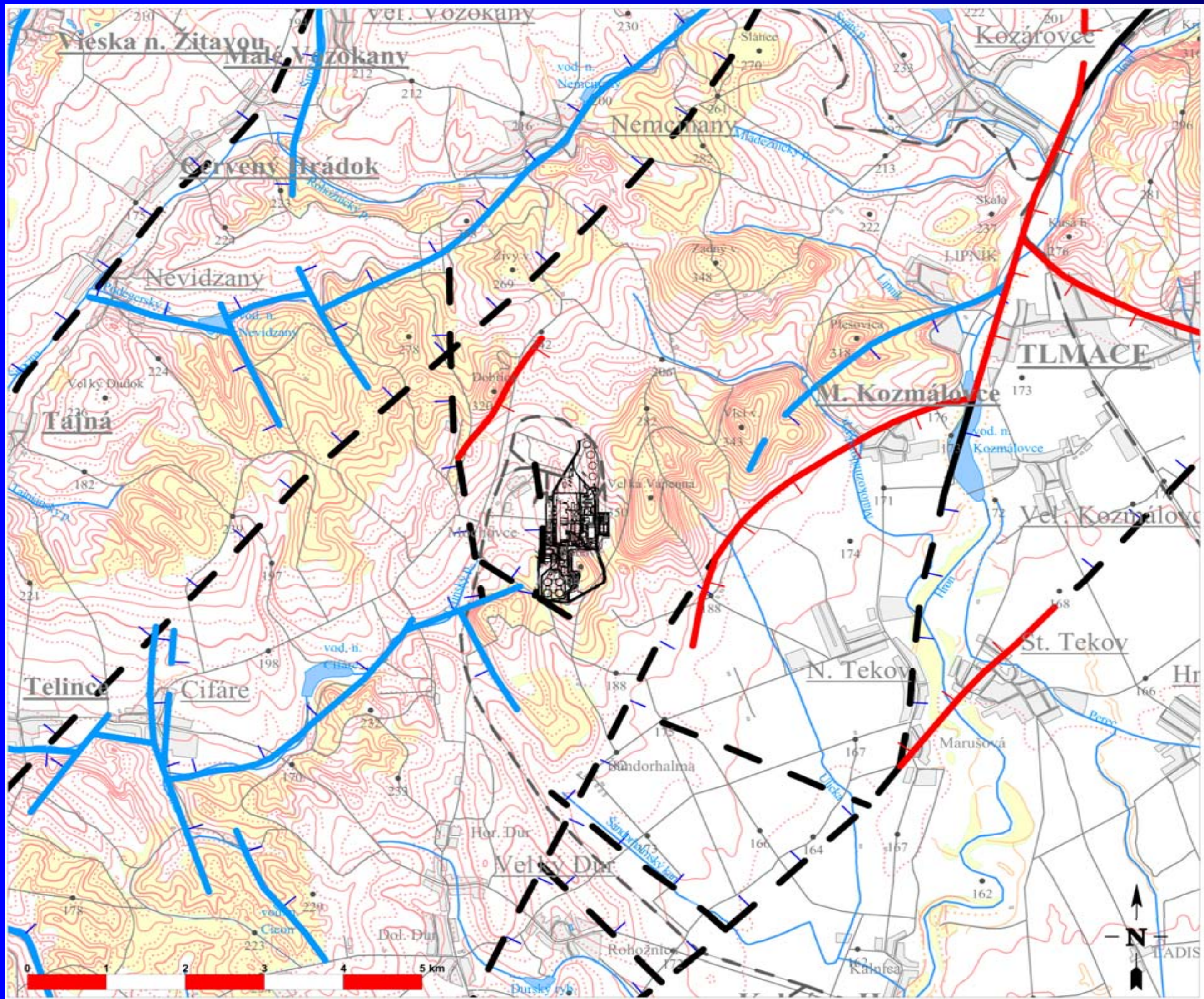
Seismotectonic model





Bohunice NPP near region

Seismotectonic model



EMO

near region

Seismotectonic model

Minimum magnitude

M = 5 (M_s = 4.33, I_o about 6° EMS-98)

Such a value of m_0 is suitable for NPPs
and other similar building structures.

An earthquake of this magnitude or a weaker one should not damage the NPP.

Seismotectonic model

Maximum magnitude – far region

Methods

- adding certain value to the maximum observed magnitude
- Gumbel type III asymptotic distribution of extreme values
- Wells & Coppersmith (1994) relationships

Data

- earthquake data - first two methods; small number of data -> one M_{MAX} value assessed for basic geological tectonic unit (W. Carpathians), i.e. for group of the source zones
- geological-tectonic data - third method; only for Dobrá Voda source zone

Seismotectonic model

Maximum magnitude – far region

W. & C. for D. Voda

Seismotectonic model

Maximum magnitude – far region

Source zone(s) in	1st	2nd	3rd	4th
	alternatives			
W. Carpathians	6.3	6.8	6.2	6.2
Dobrá Voda	6.3	6.8	6.2	6.5/6.6
Eastern Alps	5.9	6.4	5.8	5.8
Panonnian basin	6.3	6.8	7.1	7.1
Background	5.5	5.5	5.5	5.5

magnitude: M_S

Seismotectonic model

Maximum magnitude – Mochovce near region

Methods

- Wells & Coppersmith (1994) relationships

Data

- geological-tectonic data – real area of the fault

Fault	***M***
Kozárovce	4.7
Kozmálovce	4.4
Tlmače	4.9
Dobrica	3.2
Tekov	3.8
Kozárovce+Kozmálovce+Tlmače	5.2
Kozárovce+Kozmálovce	4.9
Kozárovský+Tlmače	5.1

Seismotectonic model

Magnitude-frequency relationships – far region

Maximum likelihood method

Two ways of selecting earthquakes for each source zone

- only earthquakes which are within the source zone
- also earthquakes from larger region around each of the zones in order to take into account error in location of earthquakes

Seismotectonic model

Magnitude-frequency relationships – far region

Two ways of computing b value

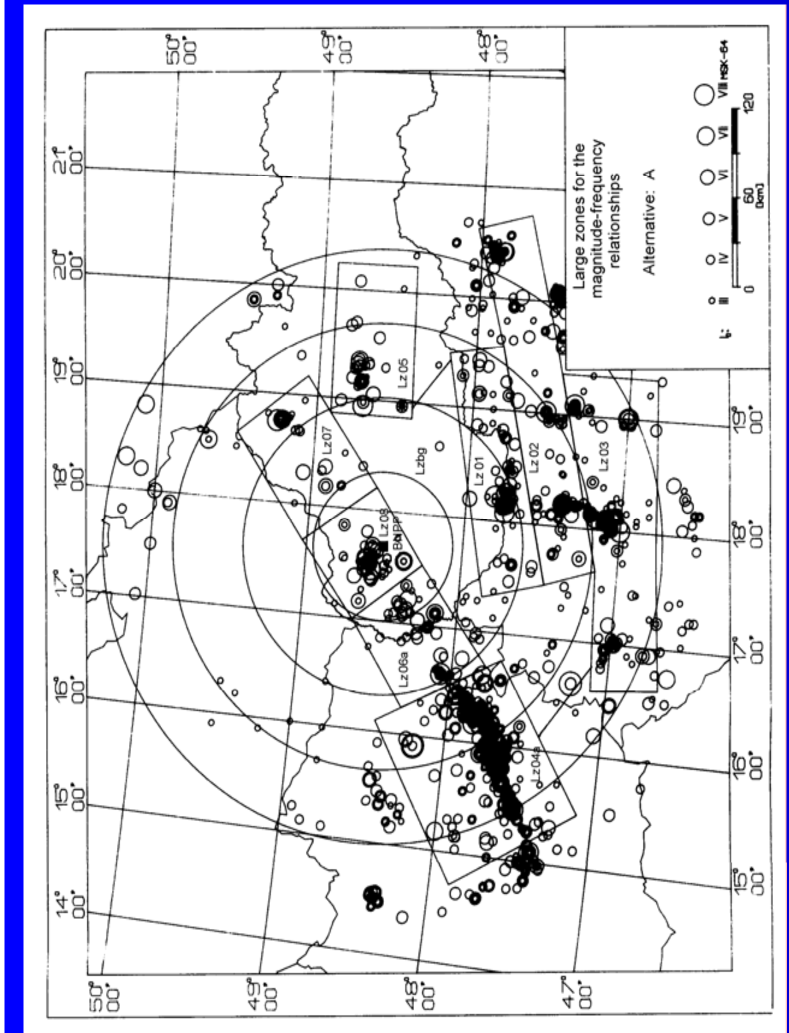
- from data for individual source zones
- from the aggregated data of source zones

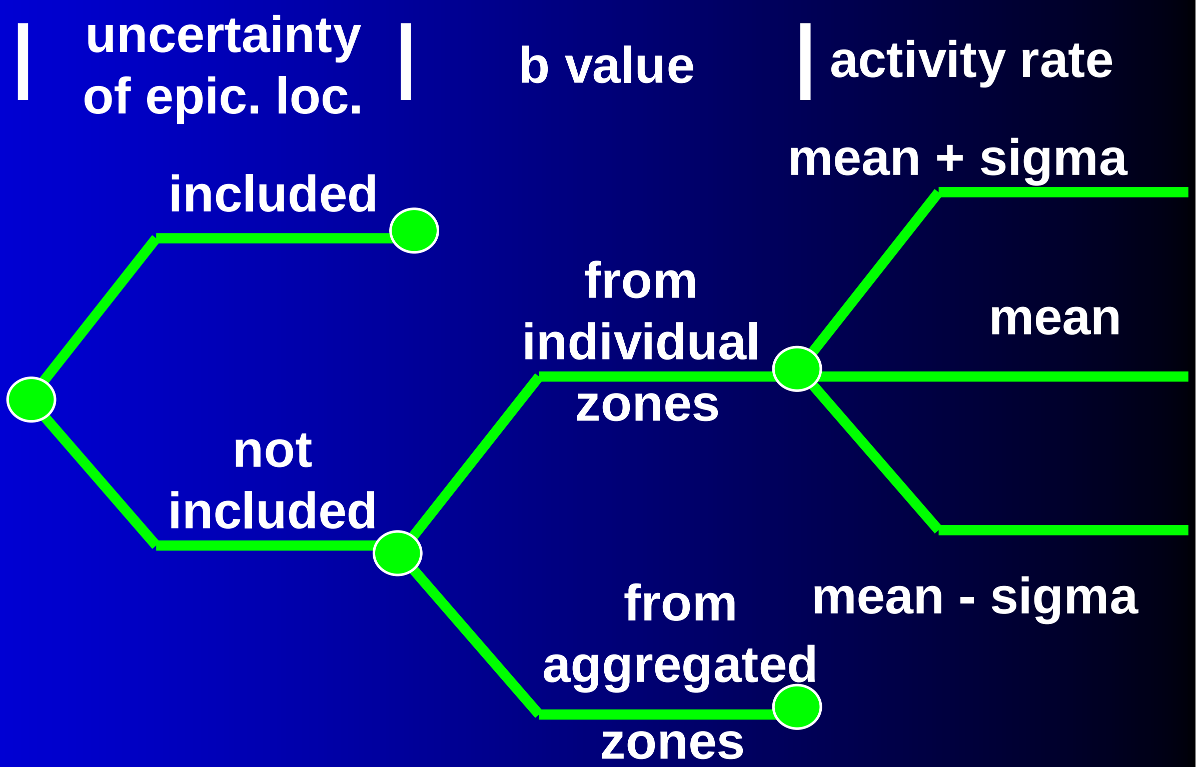
Three estimates of activity rate

- mean and mean +/- one standard error

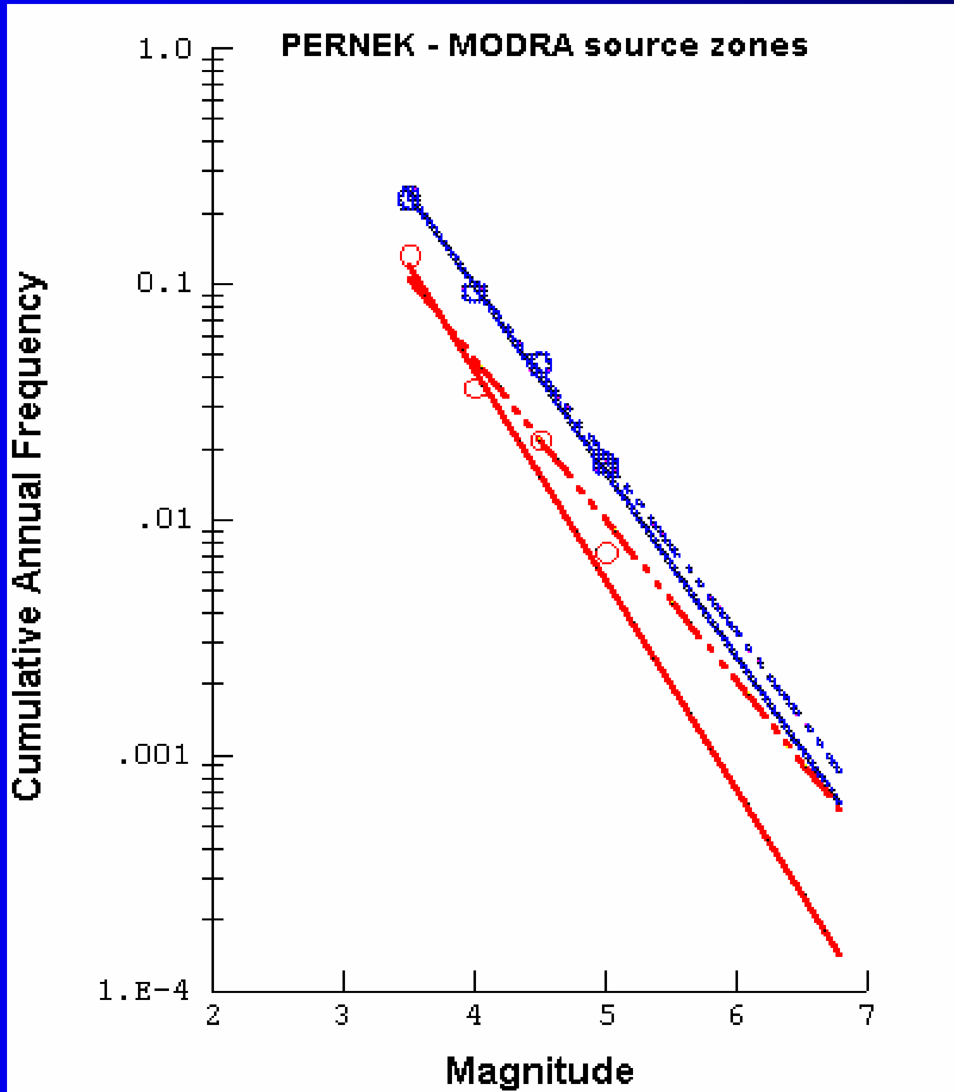
Seismotectonic model

Magnitude-frequency relationships – far region





Seismotectonic model



Seismotectonic model

Magnitude-frequency relationships – near region

- slip-rate approach
  - Campbell (1983)
  - computation of *a* values

- b value – background source zone
- average fault area from geological data
- average slip from geological data

Attenuation

Intensity attenuation in Western Carpathians

Bystrická et al. (1997)

from isoseismal radii:

$$I = 1.637 - 1.183 \log(R) - 0.015\,R + 0.783\,I_0$$

from intensity data points:

$$I = 2.204 - 1.058 \log(R) - 0.013\,R + 0.618\,I_0$$

I - site intensity in the epicentral distance R

I_0 - epicentral intensity

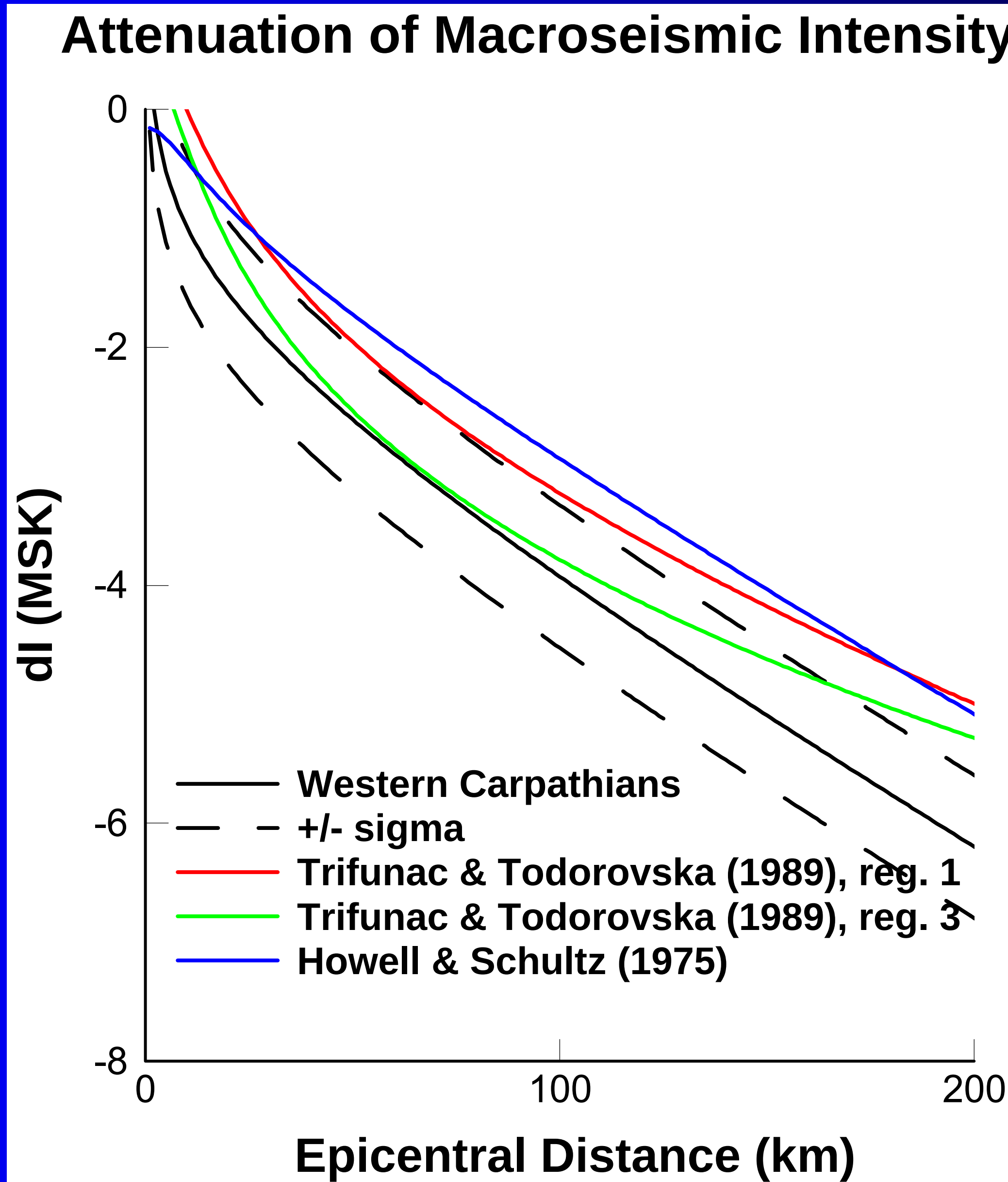
Attenuation

Selection of analogous regions

- there are no strong motion recordings
  in the Western Carpathians
- macroseismic intensity - the only available data
- PGA and PSA relationships - from analogous regions
- analogous regions selected
  on the basis of similarity of the intensity attenuation

Analogous regions to the Western Carpathians are California and Balkan area

Attenuation



Attenuation

Selection of PGA and PSA attenuation relationships for analogous regions

Criteria for selecting attenuation relationships:

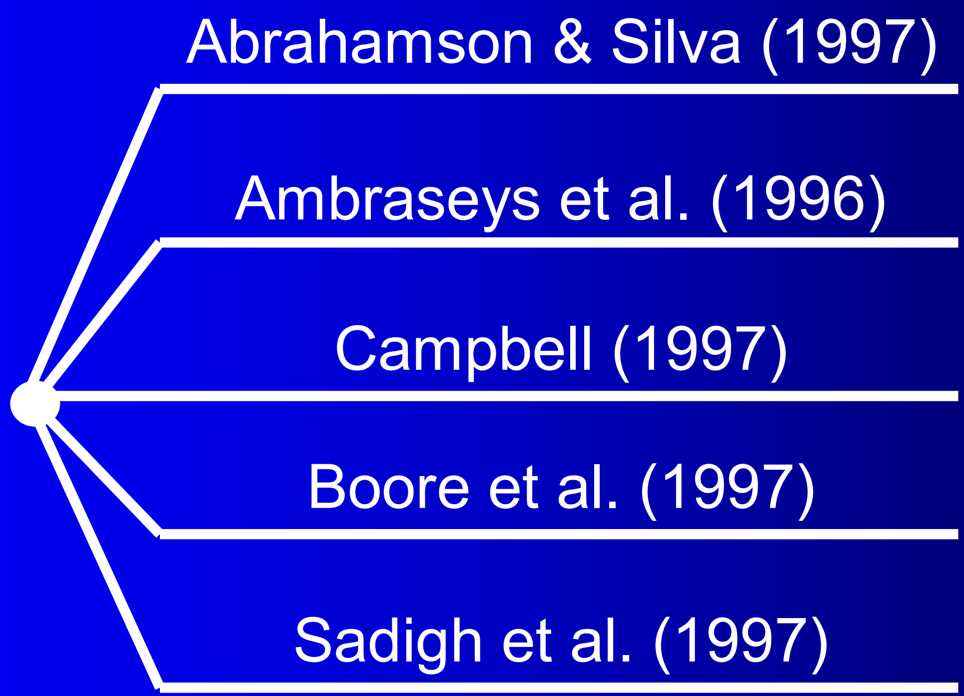
- The attenuation relationship is derived for both PGA and PSA

- The magnitude and distance intervals for the attenuation relationships for PGA and PSA. The interval of periods for the attenuation relationships for PSA

- The attenuation relationship is derived from data on earthquakes of different type of slip or allows to choose an unknown type of slip.

- The type of site conditions

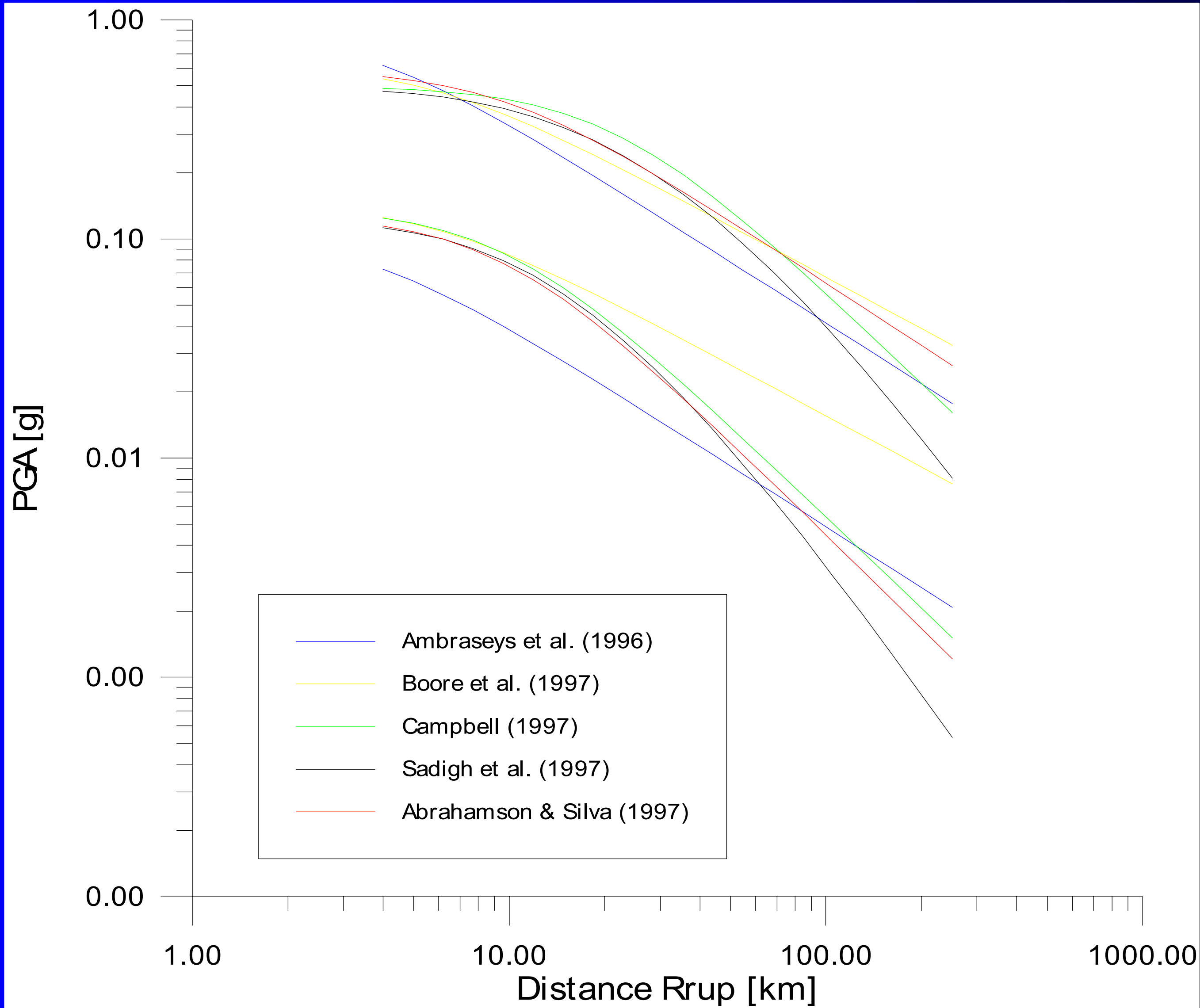
Attenuation



The attenuation relationships are for

- horizontal component
- 5% of critical damping
- PGA and 0.1, 0.2, 0.3, 0.5, 0.75, 1.0, 1.5, 2.0s periods

Attenuation



Attenuation

PGA and PSA attenuation relationships are available for M or M_s

Magnitude-frequency relationships are determined for M_s

Conversion between M and M_s

Ekstrom & Dziewonski (1988)

$$\log M_0 = \begin{cases} 19.24 + M_s & M_s < 5.3 \\ 30.20 - \sqrt{92.45 - 11.40 \, . \, M_S} & 5.3 < M_s < 6.8 \\ 16.14 + 1.5 \, . \, M_s & M_s > 6.8 \end{cases}$$

Hanks & Kanamori (1979)

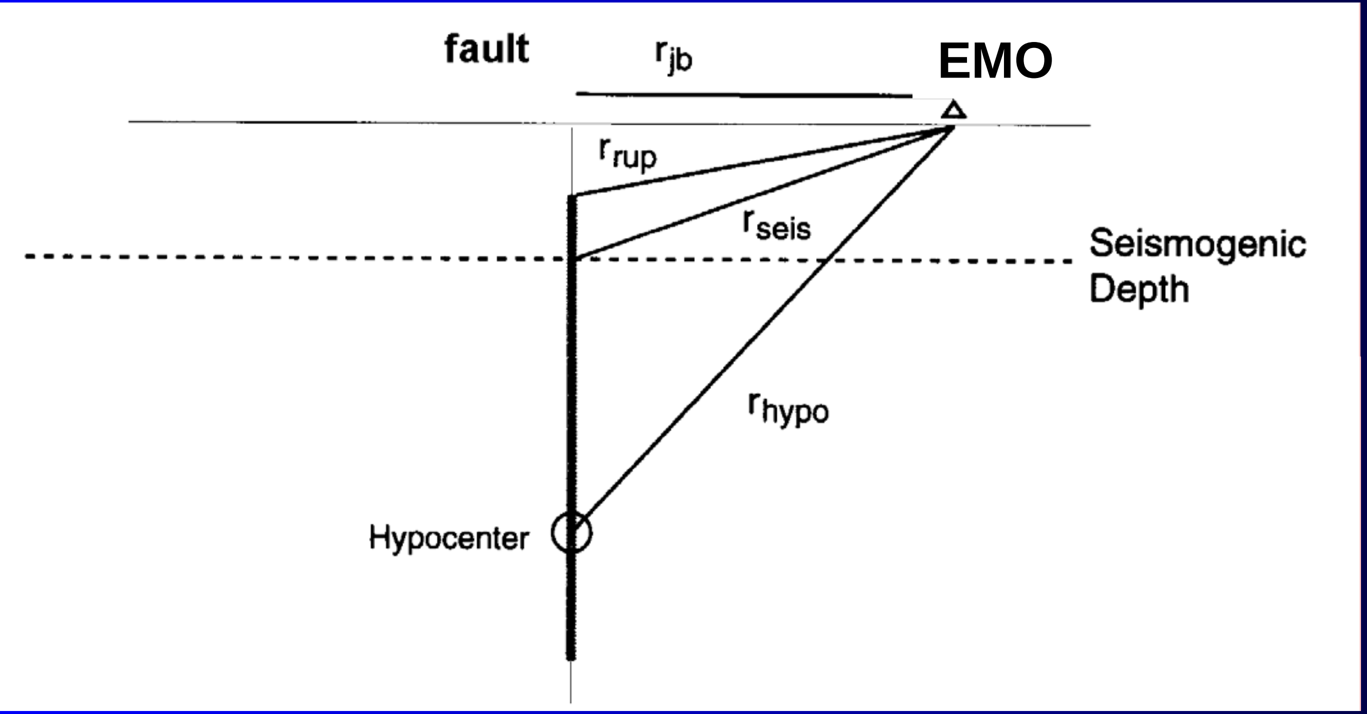
$$M = (2/3) \, . \, \log(M_0) - 10.7$$

M_0 - seismic moment

M_s - surface-wave magnitude

M - moment magnitude

Attenuation



Hazard computation should be performed for r_{jb}

PGA and PSA attenuation relationships need also r_{rup} and r_{seis}

Attenuation

Conversion for the EMO site

Campbell (1997)

$$HBOT = 15\ km$$

$$r_{rup}^2 = (r_{jb}^2 + d_{seis}^2) \text{ and } HTOP = 0\ km$$

$$r_{seis}^2 = (r_{jb}^2 + d_{seis}^2) \text{ and } HTOP = 3\ km$$

$$d_{seis} = (HBOT + HTOP - W \cdot \sin(a)) + HTOP$$

d_{seis} - average depth to the top of the seismogenic rupture zone

HTOP - depths to the top of the fault (r_{rup}) or seismogenic part of the crust (r_{seis})

HBOT- the bottom of the seismogenic part of the crust

a - a dip angle of the fault plane (90° in our case)

W - expected width (down-dip dimension) of the fault rupture in *km* (from Wells & Coppersmith, 1994 formula)

Seismotectonic model and Attenuation

Summary

- uncertainties in the databases
- use of various methods for computation of input parameters

Alternative seismotectonic models and alternative attenuation relationships

Probabilistic computations

Construction of the logic tree

Logic tree (LT) (Reiter, 1990)

- LT is the decision flow path consisting of nodes and branches.
- LT allows to include various sets of input parameters. Each parameter is represented by a node. Branches represent alternative discrete values of the parameters. Likelihood of each branch is assessed.
- One path in the LT represents scenario.
- The sum of the likelihoods of all scenarios has to be 1.0

Probabilistic computations

Branch likelihoods

- assessed by expert judgment

Most likely alternatives in the far region

- Leitha region belongs to the Western Carpathians
- M_{MAX} values computed from Gumbel type III distribution and the Wells & Coppesmith (1994) relationships
- the uncertainty of epicenter location is included in computations of the magnitude-frequency relationships
- b values are computed from aggregated source zones

Probabilistic computations

Branch likelihoods

Most likely alternatives in the Bohunice near region

- dummy-fault models for Dobrá Voda source zone

Probabilistic computations

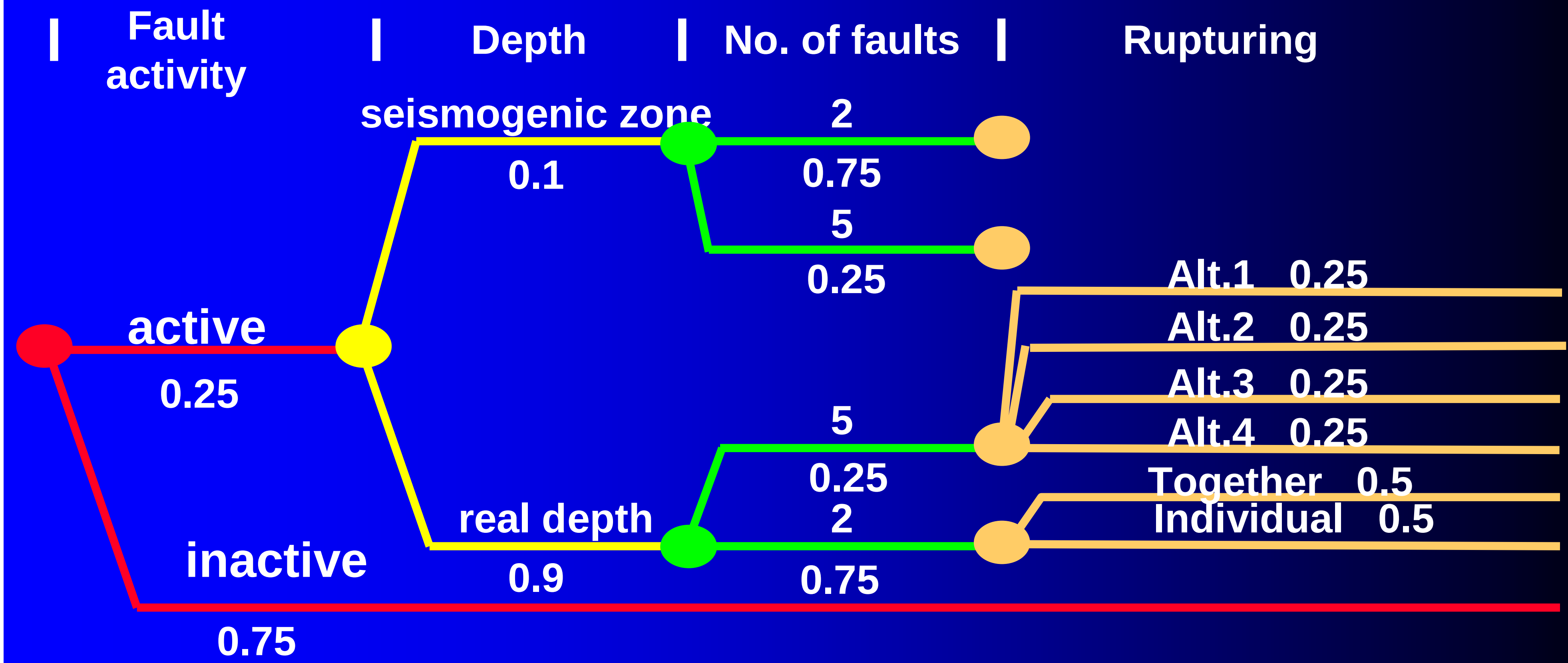
Branch likelihoods

Most likely alternatives in the Mochovce near region

- The faults in the near region are inactive
- Depth of the faults corresponds to the estimated depth
- If the faults are active, only two faults are active (not all five)
- All rupturing models have the same preference

Probabilistic computations

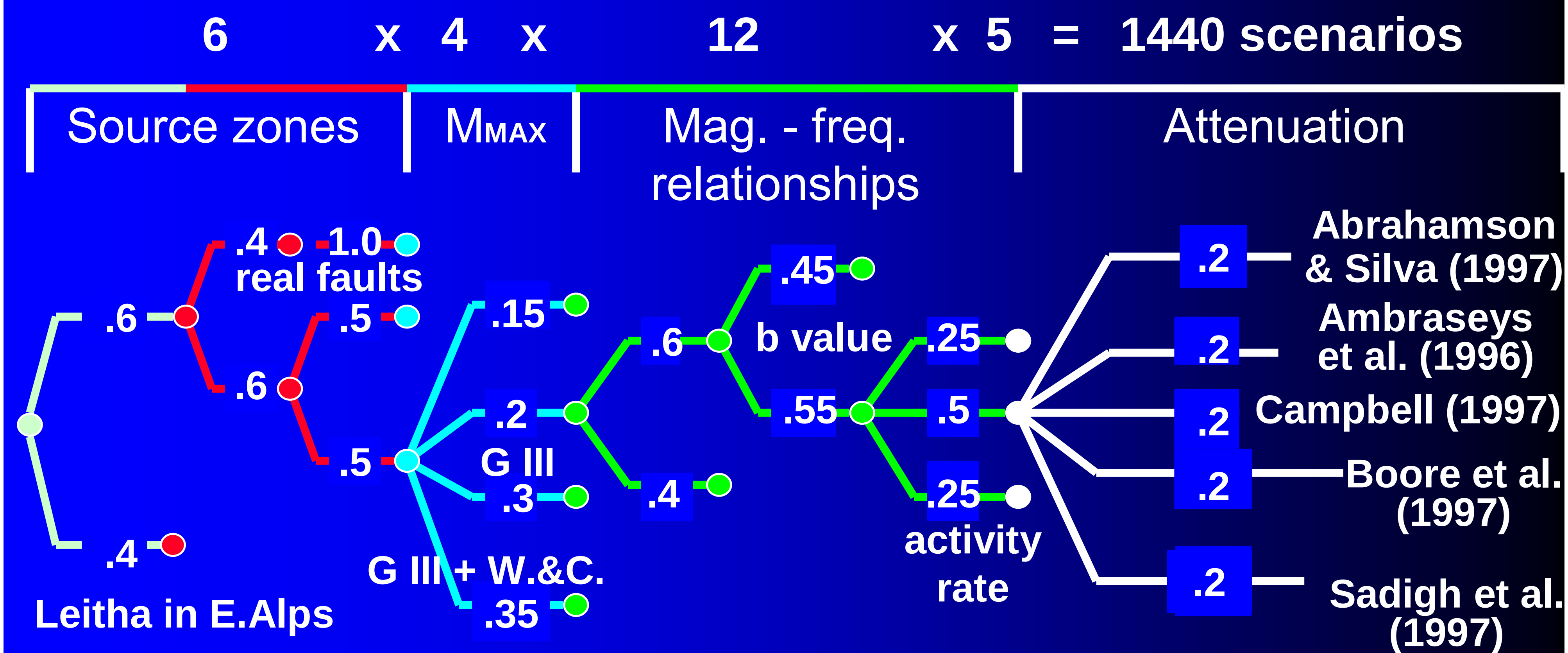
Modeling uncertainties: Logic tree – Mochovce NPP near region



Total weighted average occurrence period of earthquakes with M>5 is T > 10 000 years

Probabilistic computations

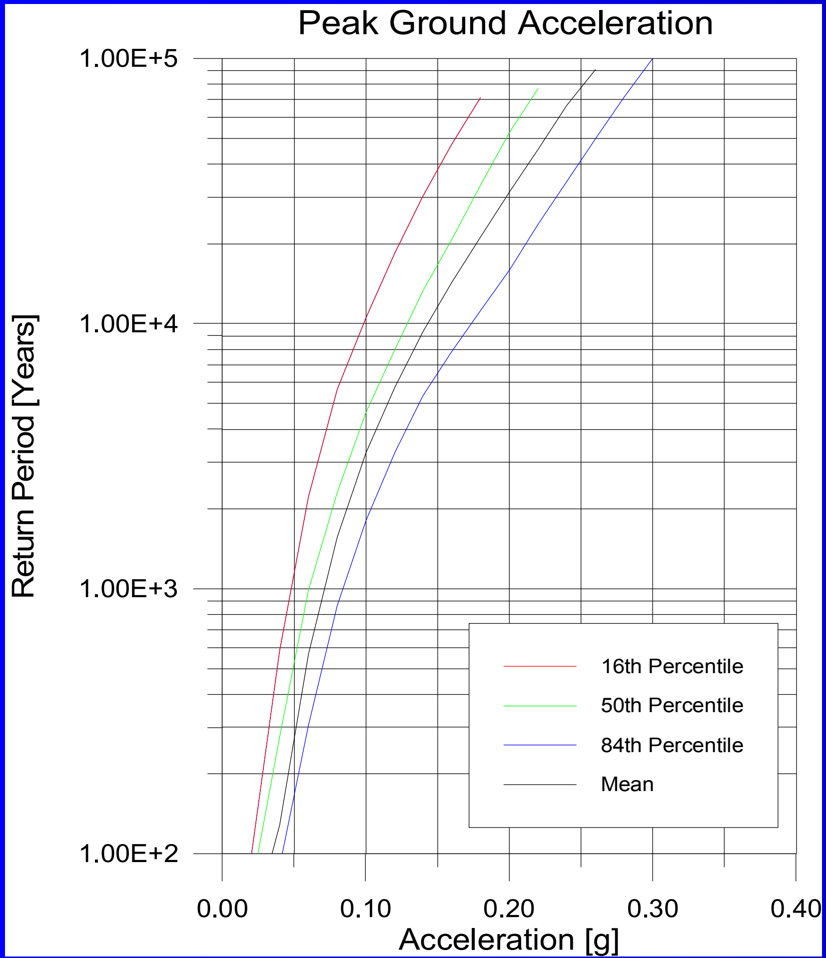
Modeling uncertainties: Logic tree – far region

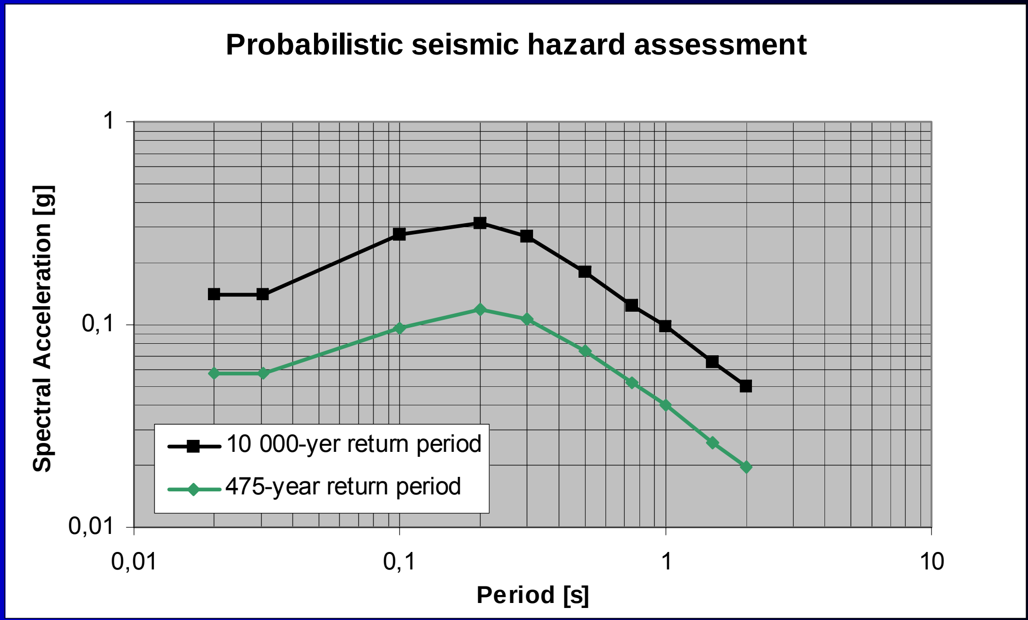


Probabilistic computations

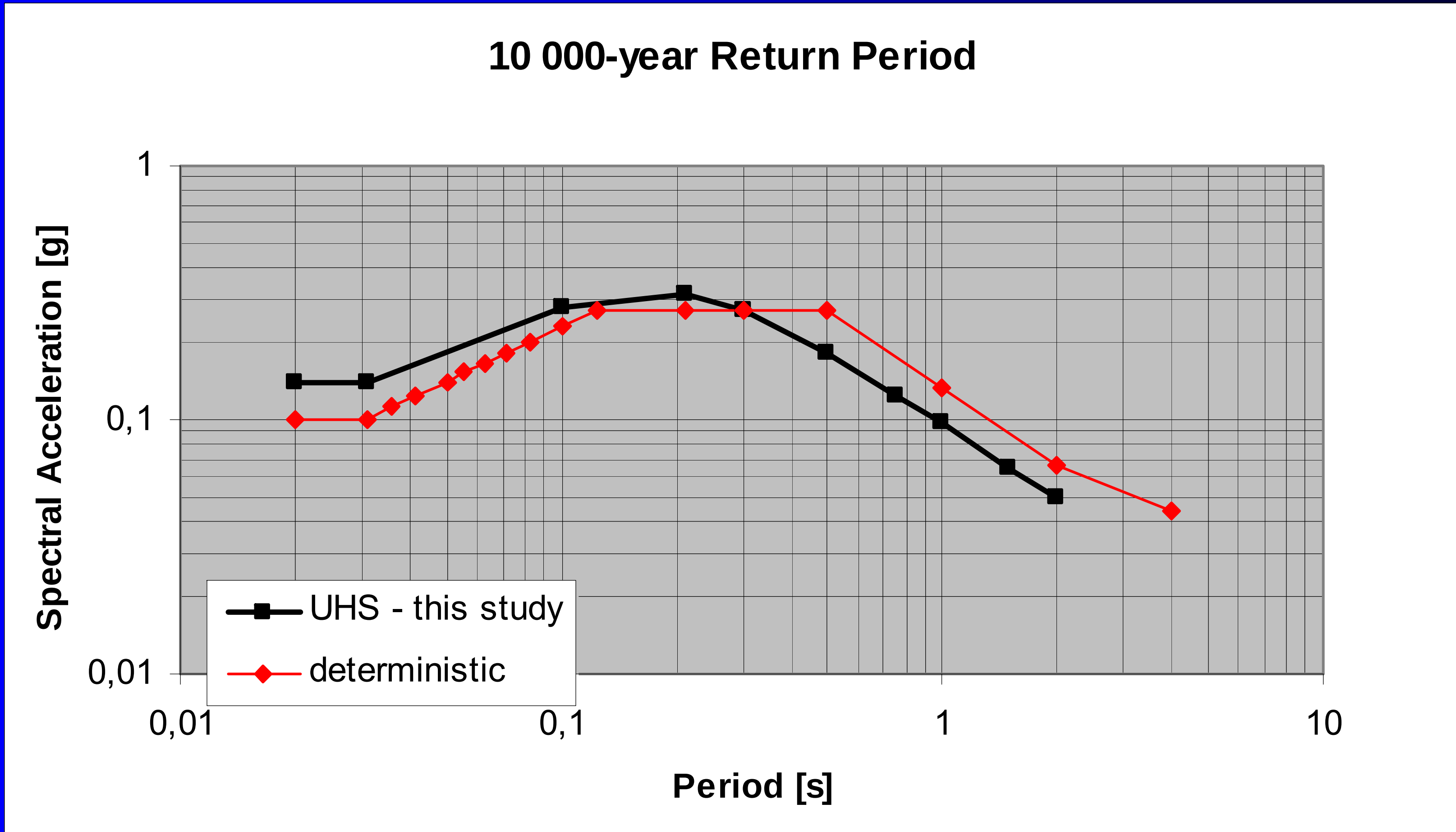
Mochovce NPP

Horizontal component



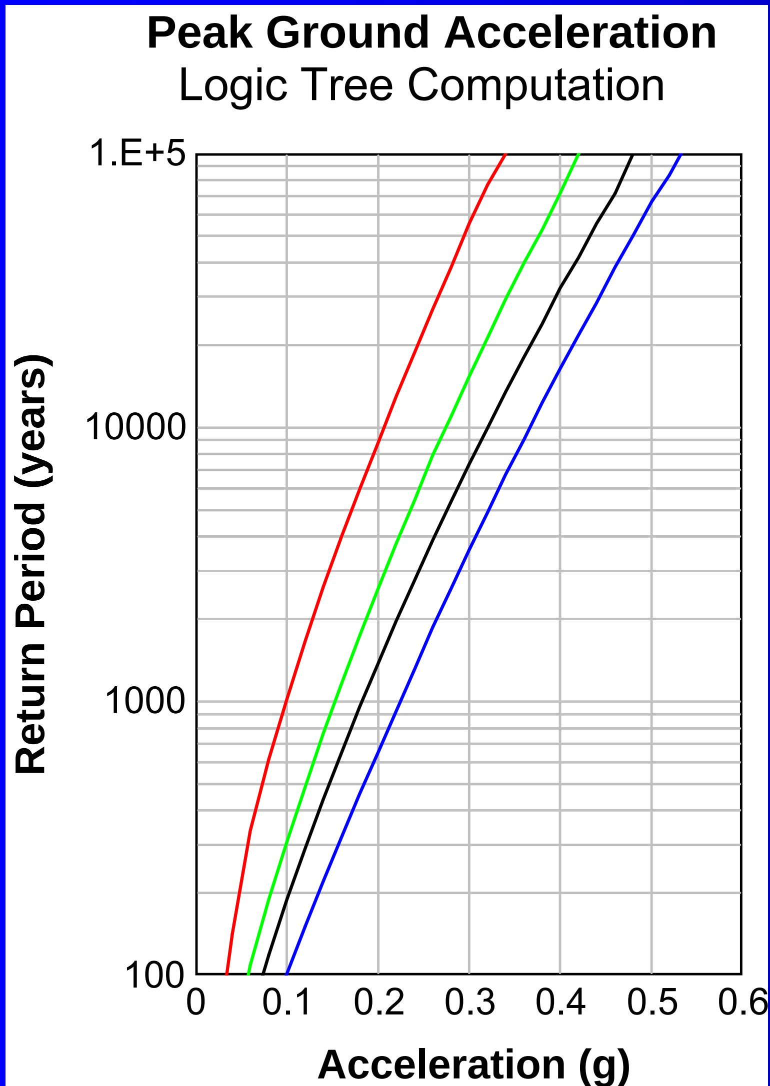


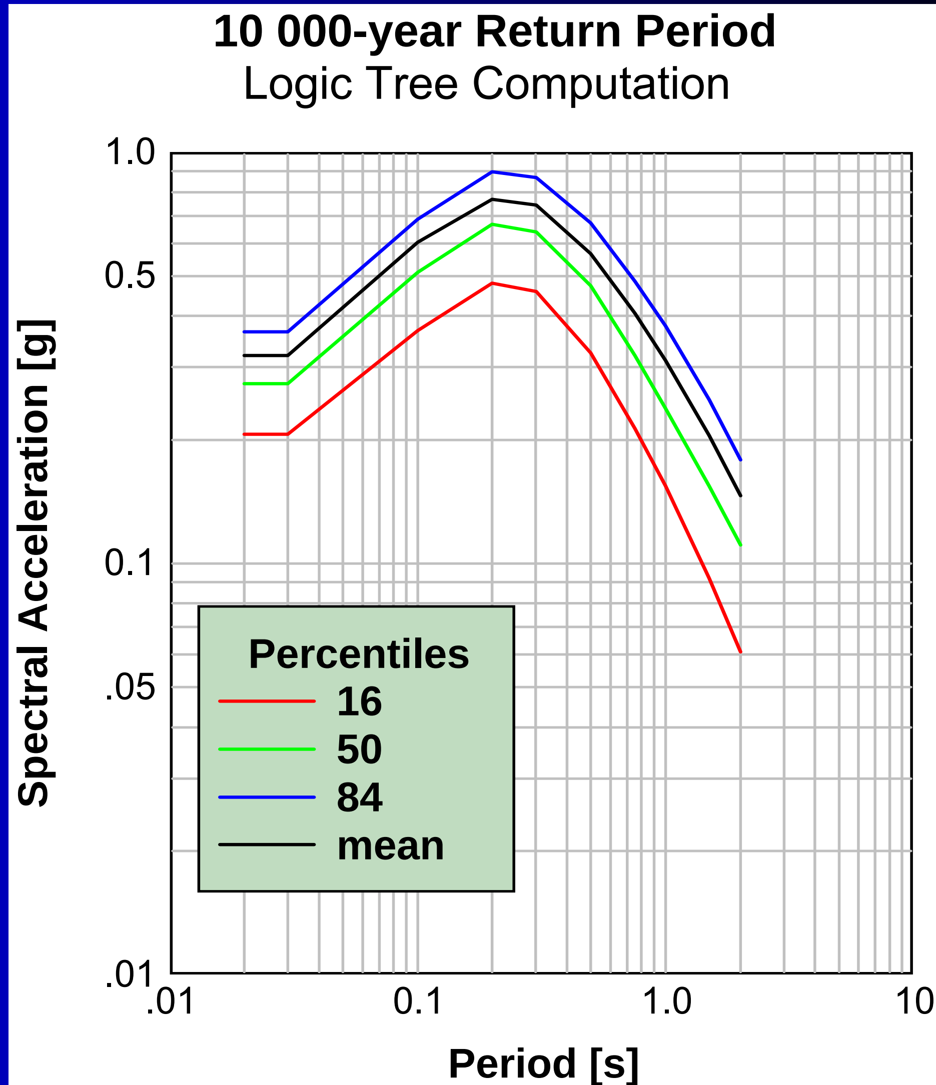
Probabilistic computations



Probabilistic computations

Bohunice NPP





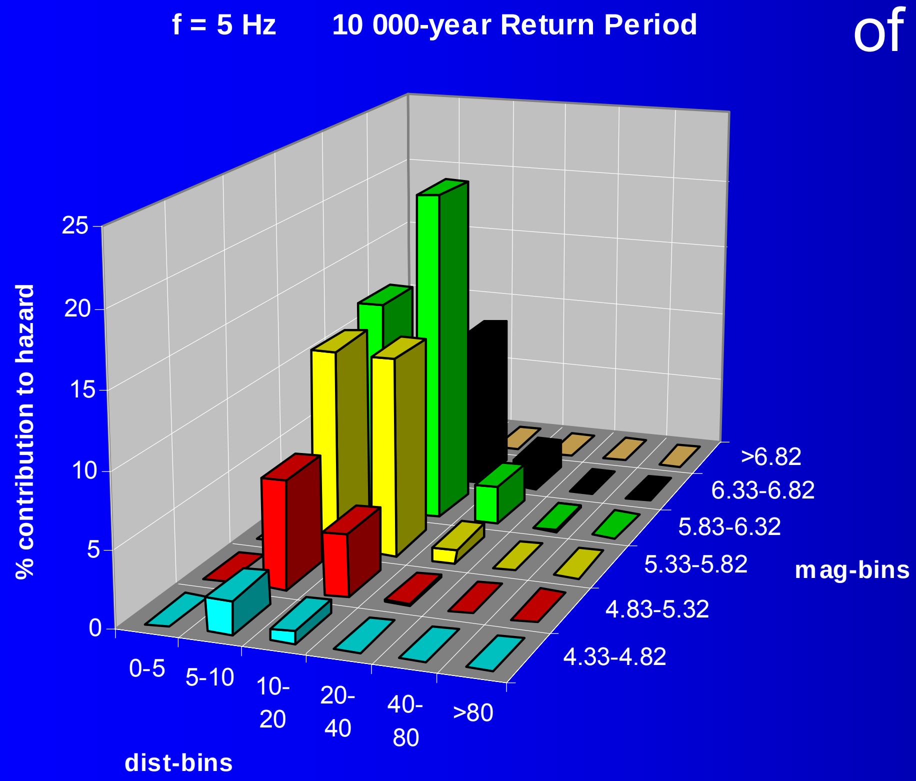
Probabilistic computations

De-aggregation of hazard computation

0.2s UHS value

- the most representative period of building structures
at the Bohunice NPP site

Probabilistic computations

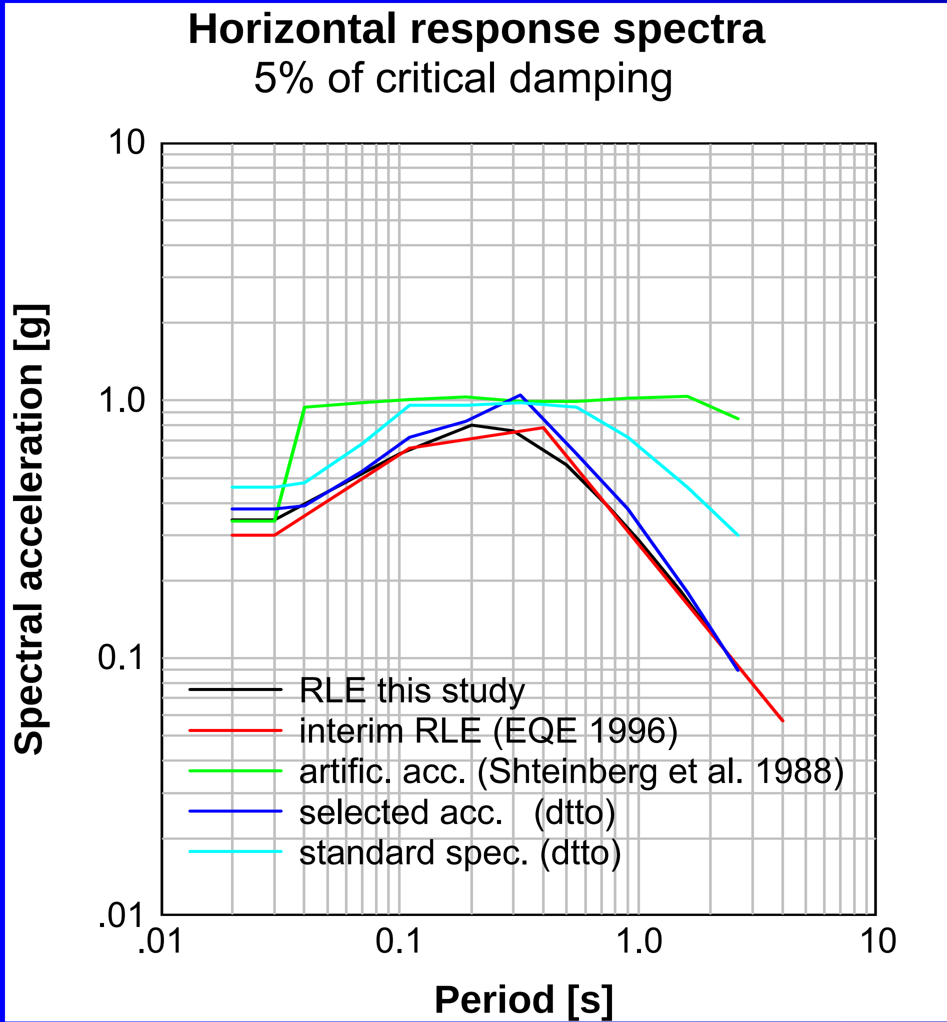


Magnitude
of the controlling earthquake M_S=5.9

Distance
of the controlling earthquake
r_{JB}=12.2 km

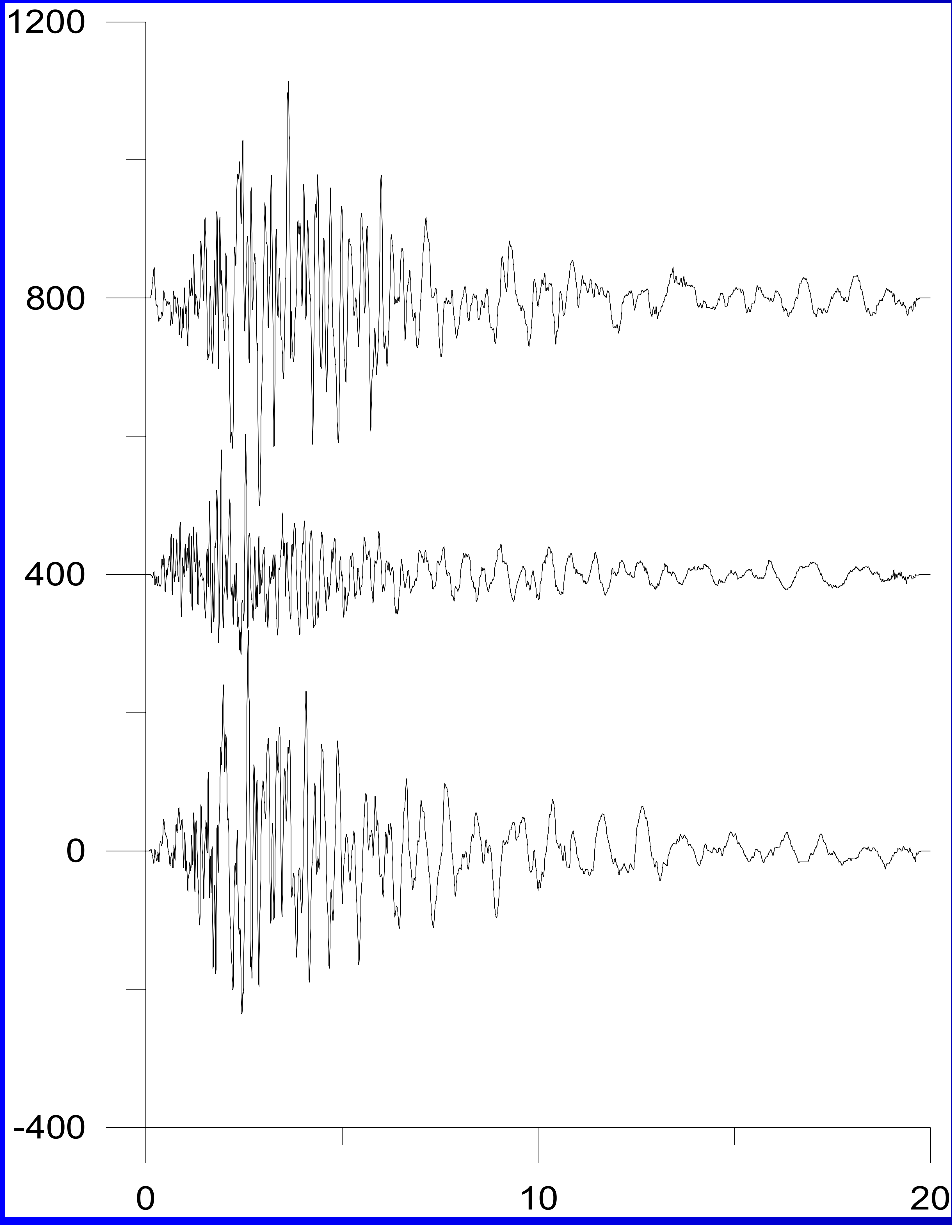
Distance of the controlling earthquake is within the Dobrá Voda source zone

Probabilistic computations



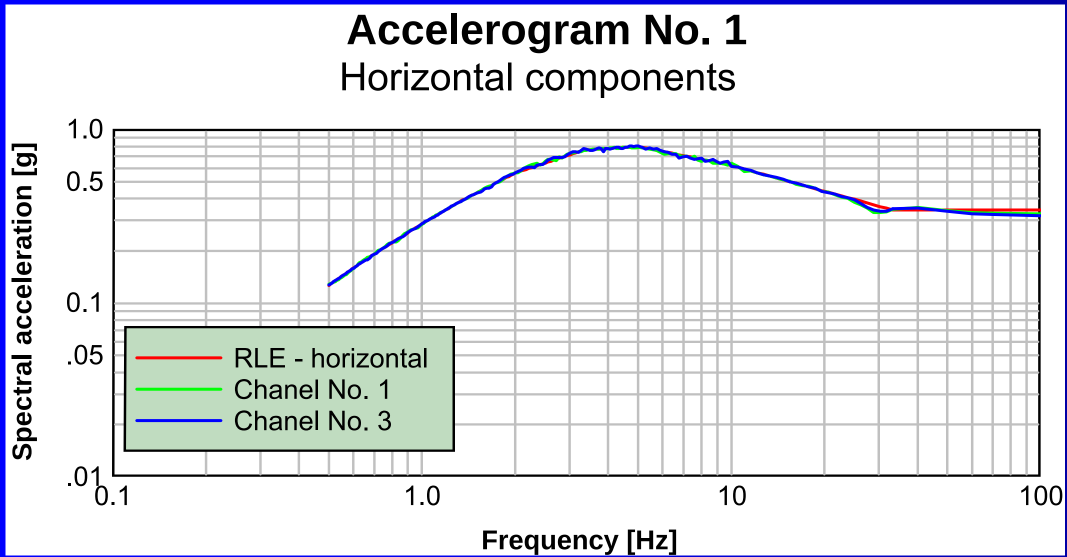
- previous deterministic and new probabilistic PGA values are similar
- previously estimated response spectra by Shteinberg et al. (1988) differ from the RLE response spectrum
- the RLE response spectrum is within 15% of the IRLE spectrum of EQE (1996)

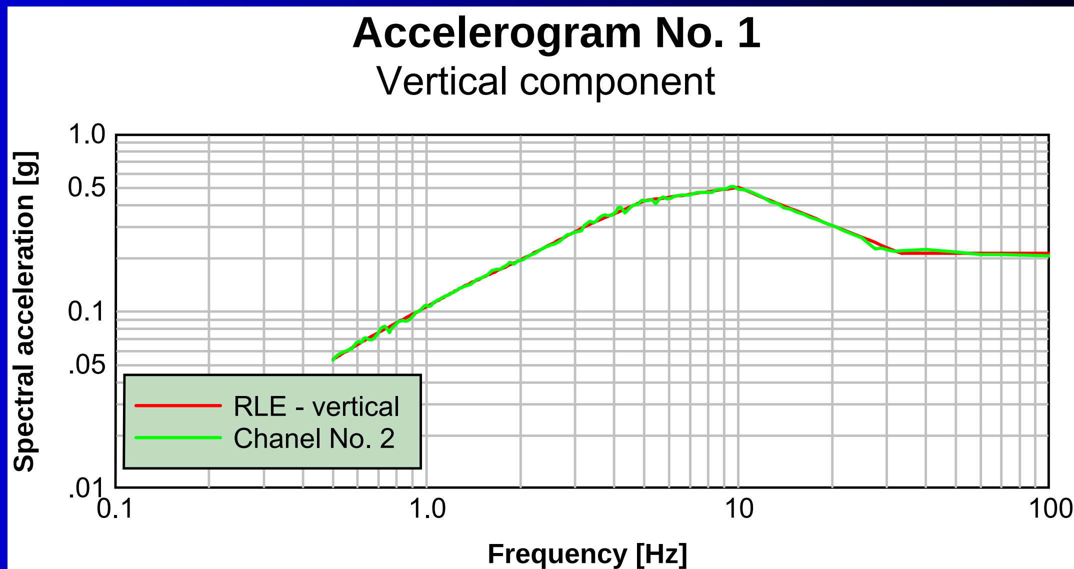
Probabilistic computations



The accelerograms were modified using the non-stationary spectral matching method of Abrahamson (1998)

Probabilistic computations





Summary

- all databases heterogeneous
  - more accurate in the near region of NPPs
- various methods used for computation of input parameters for PSHA
- logic tree used for dealing with modeling uncertainties
- hazard computations for all hazard scenarios
- de-aggregation technique used for computation of characteristics of controlling earthquake
- Result: site-specific spectra and accelerograms