Some contributions to the creation of a ground motion map for deep Vrancea Earthquakes

by

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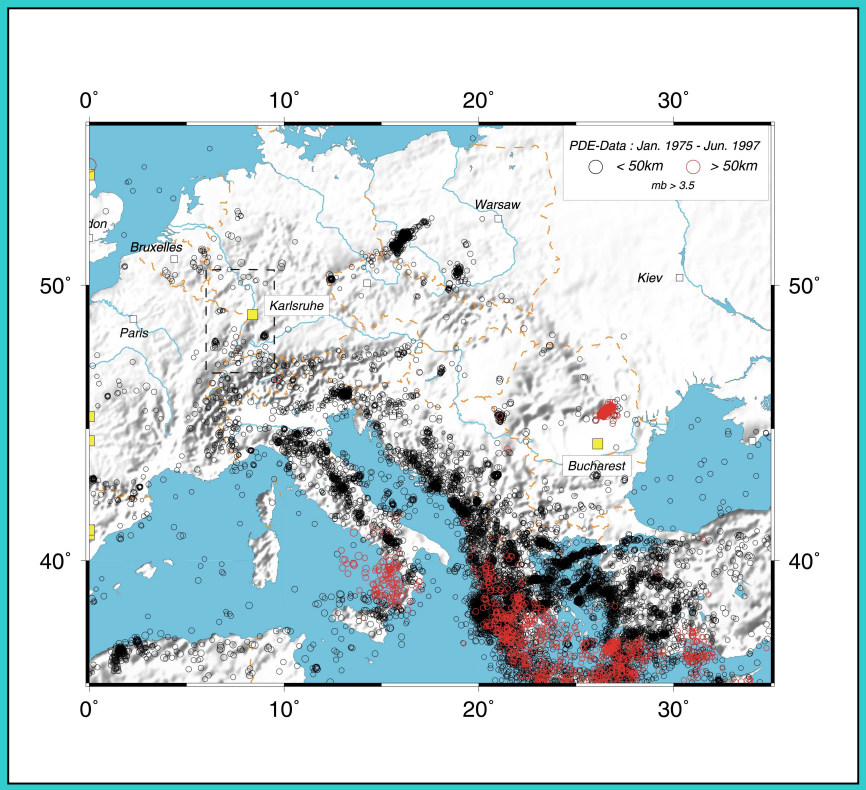
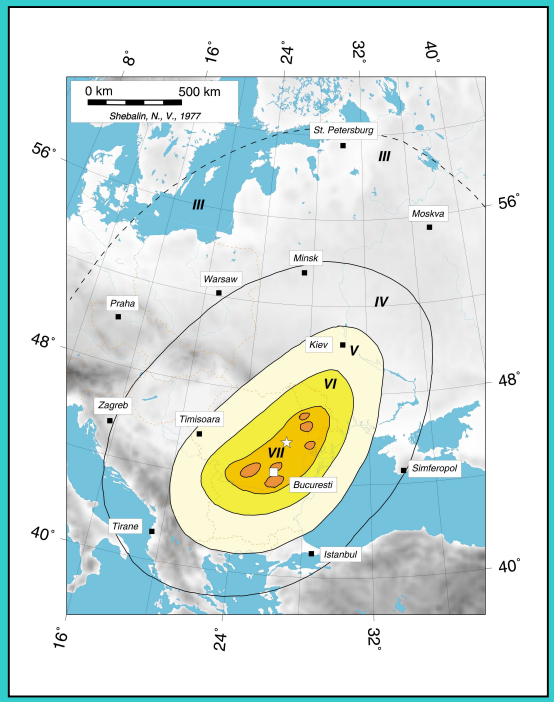
Trieste, November 30, 2004

Motivation: Why Vrancea ?



European Seismicity: 1975-1997



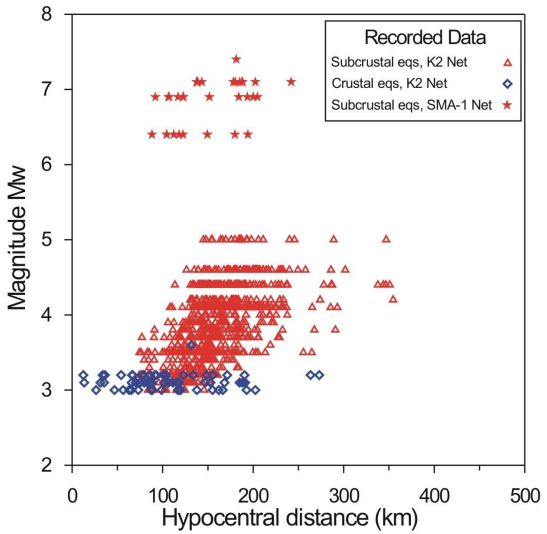
Vrancea March 4. 1977
intensity distribution

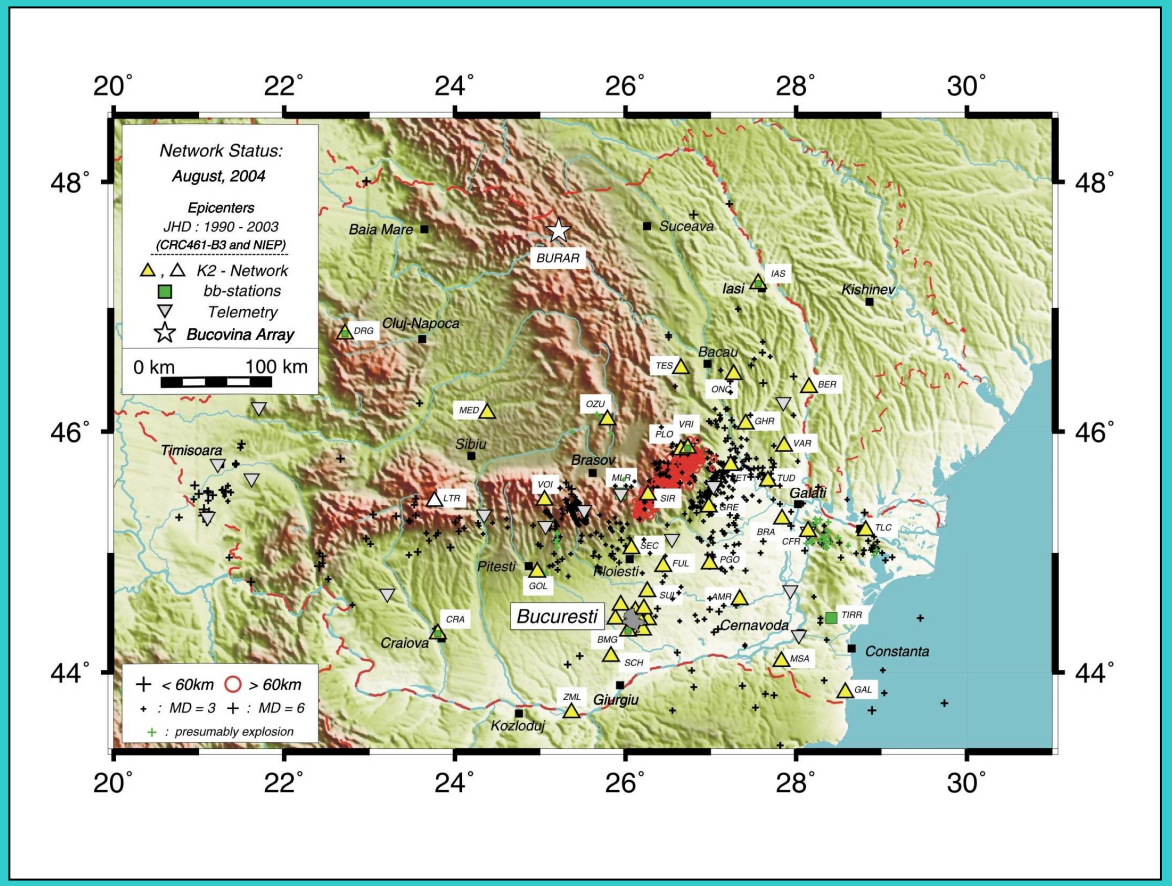
- high seismic activity
- small seismogenic area
- long historical record
- competent partners

The K2 - Network

The Network consists of 42 Kinemetrics K2 accelerograph Systems for strong and weak ground motion.

Standard configuration:
- six channels with 19 bits
- sample rate: 200 Hz per ch
- ch 1-3: 3-comp. Episensor 2g
- ch 4-6: 3-comp. velocity transducer
- GPS-time unit

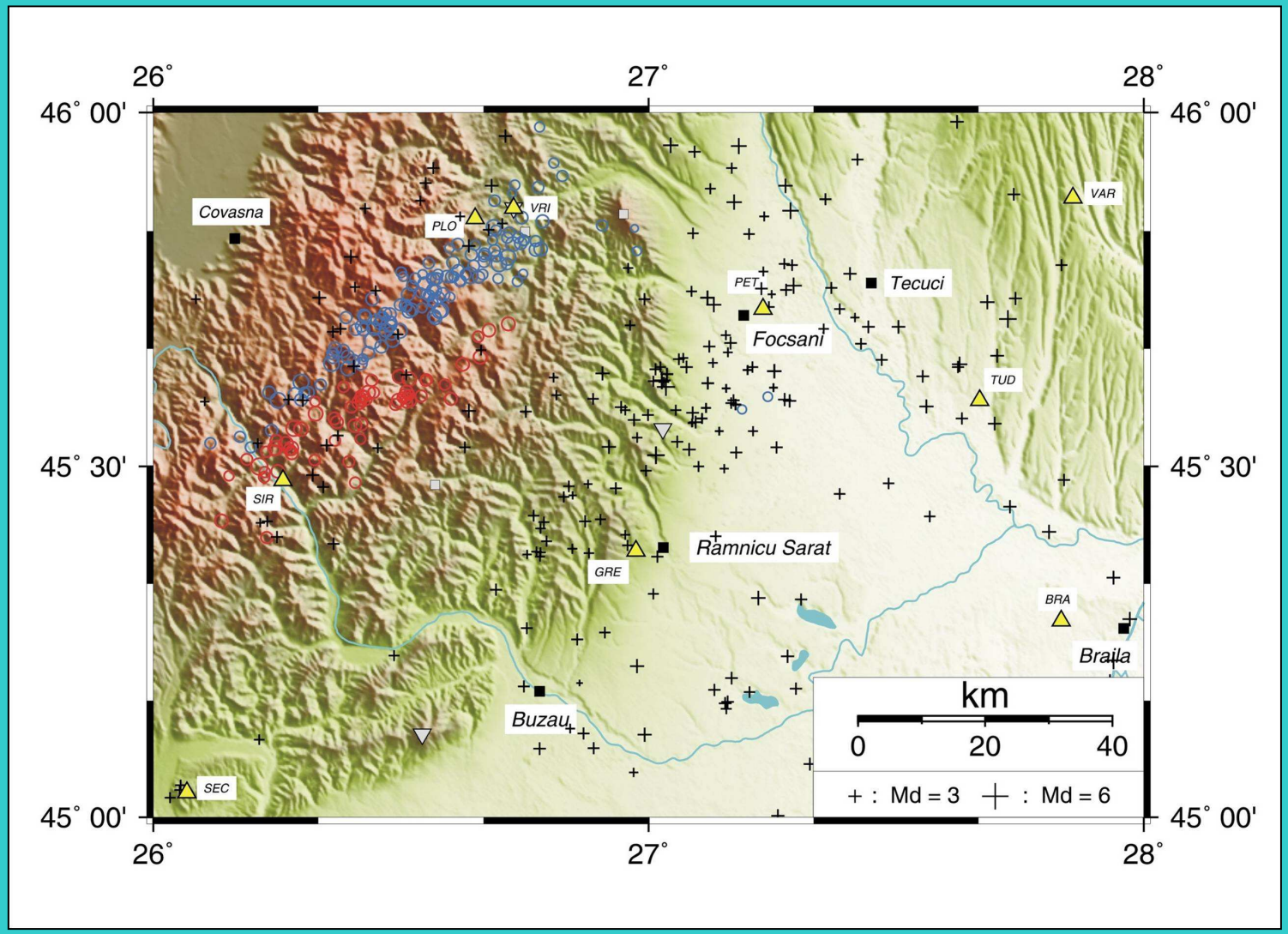




Inventory of accelerogramms

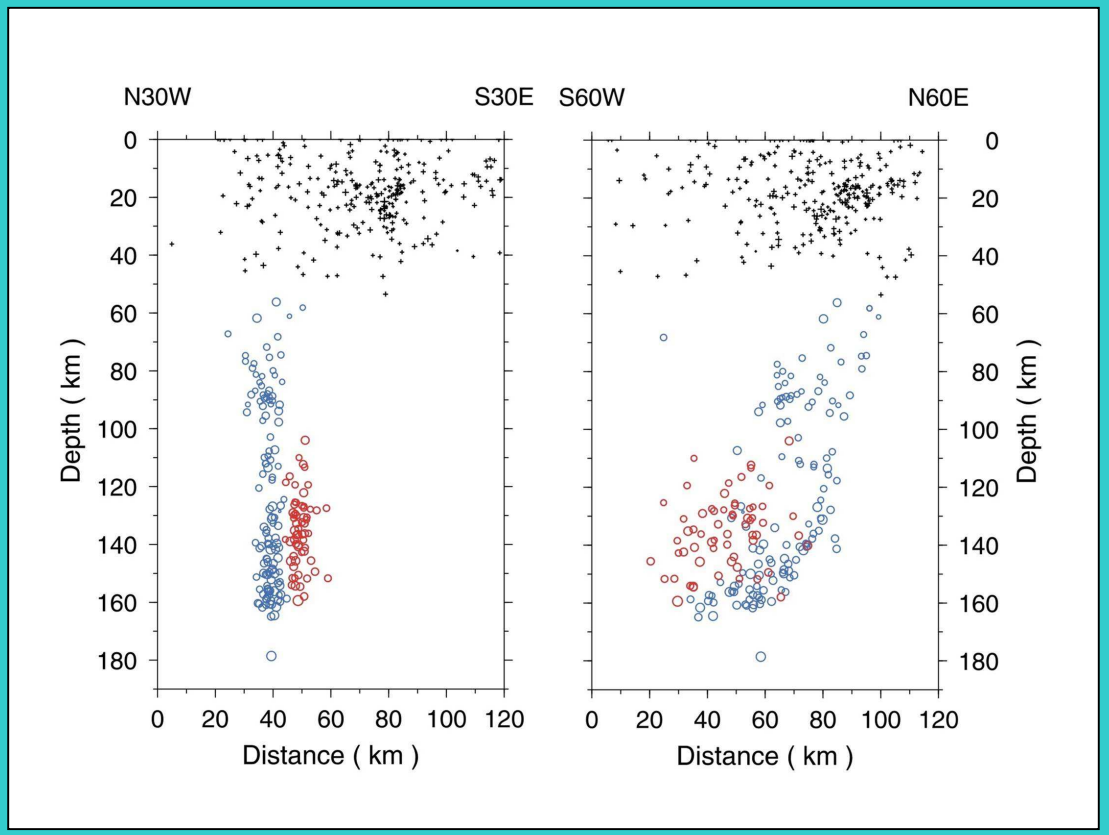
The Vrancea Source Zone

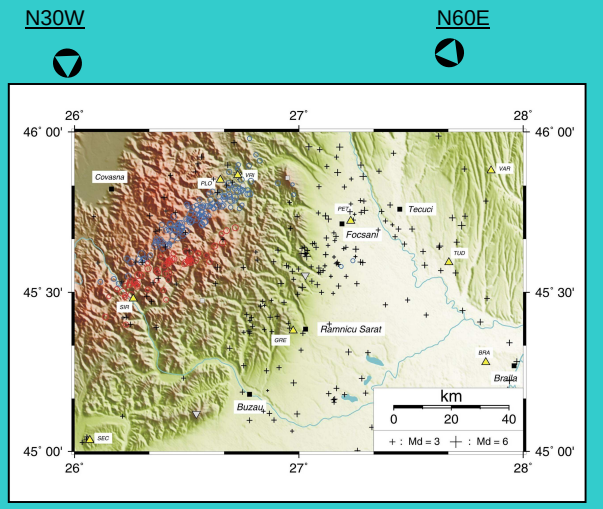
JHD of the ***1999*** Calixto-Data and the K2- and Telemetry-Data of the time period ***1997 – 2003***

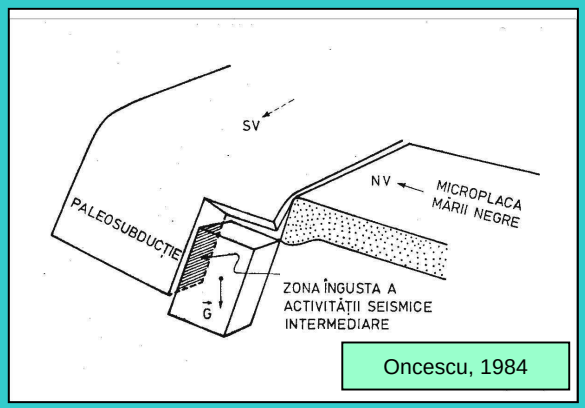


The Vrancea Source Zone

Geometry of the Seismogenic Area
Joint **H**ypocenter **D**eterminations
(Jan. 01, 1997 – Dec. 31, 2003)



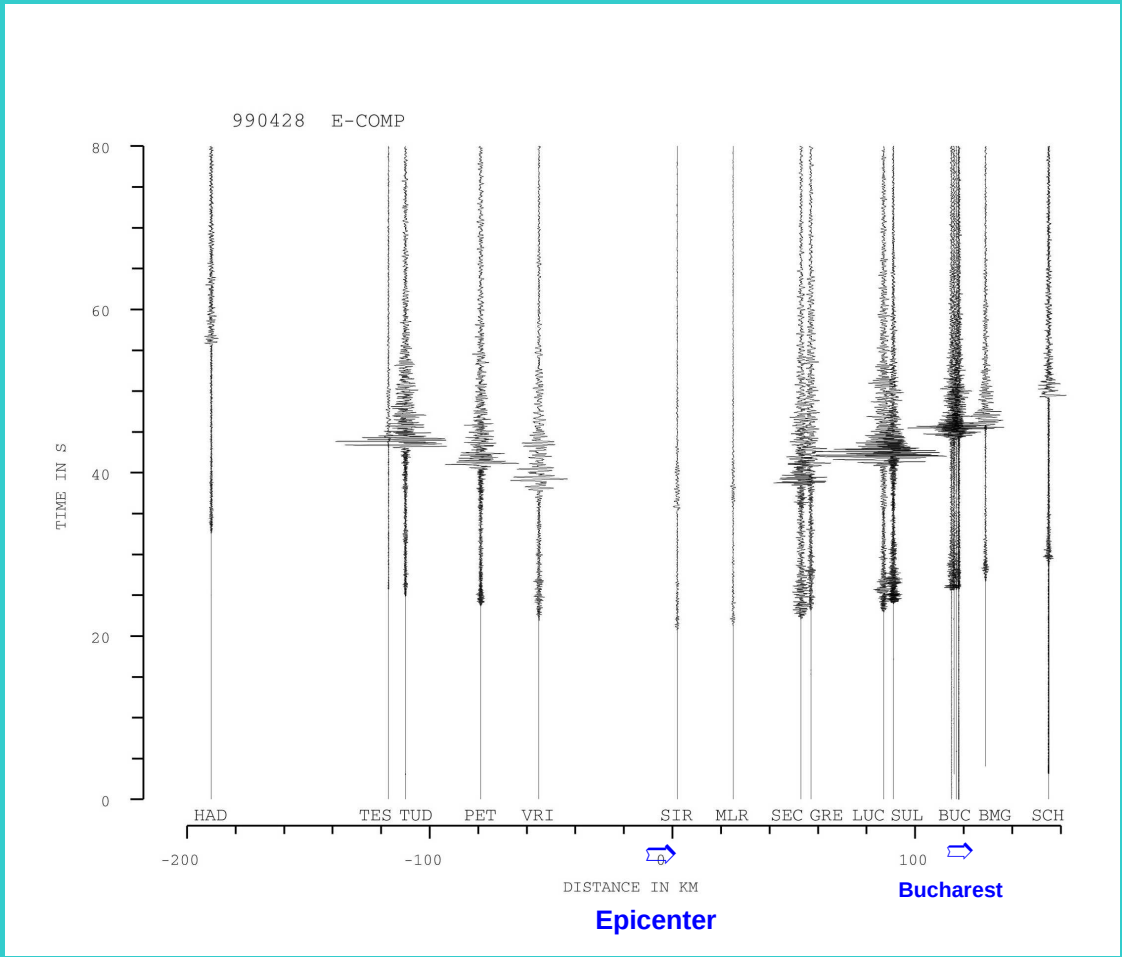




Oncescu, 1984

big events: e.g. 1986 ➤➤➤

Site Effects



NE-SW record section of the April 28, 1999 Mw=5.3 Vrancea event

Apparent increase of amplitudes with distance is a result of site effects!

In order to quantify these effects, we use the Very Hard Rock-model of Vladimir Sokolov (1998).

Site Effects
VHR-Model

The general model for the **Fourier acceleration Spectrum *A*** at a frequency ***f*** is given by:

$$A(f) = (2\pi f)^2 \cdot C \cdot S(f) \cdot D(R, f) \cdot I(f)$$

scaling factor

source spectrum

attenuation function

frequency-dependent site response

We used **several hundred** records of the K2-network from more than 120 small magnitude (M = 3.5 -5.5) earthquakes, which occurred at depths between 70 and160 km in 1996 -2002, and a **few tens** records written by SMA-1 systems during four large (M 7.4, 7.2, 6.9 and 6.3) earthquakes.

Site Effects
VHR-Model

Soil Site spectra

$$A(f) \sim S(f) \cdot D(R, f) \cdot I(f)$$

Very Hard Rock spectra

$$\underline{\boldsymbol{I(f)=1}} \qquad VHR\,(f) \sim S(f) \cdot D(R, f)$$

The ground-motion **VHR** spectral model for the Vrancea earth-quakes was obtained in the form of a single-corner-frequency f^2-spectrum (source scaling) and a 3-layers Q-model (attenuation).

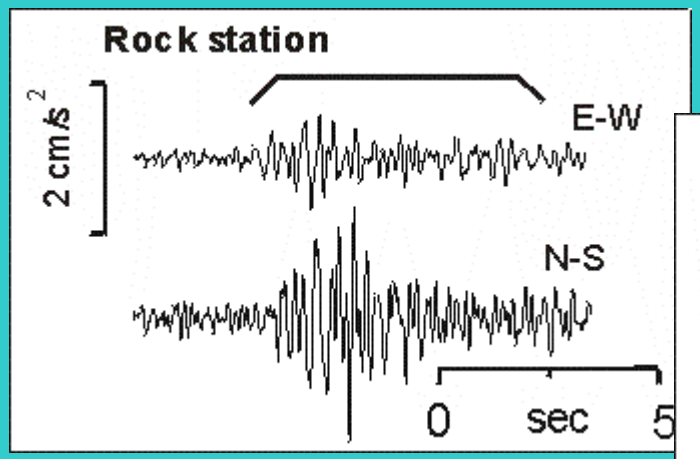
VHR spectral ratio

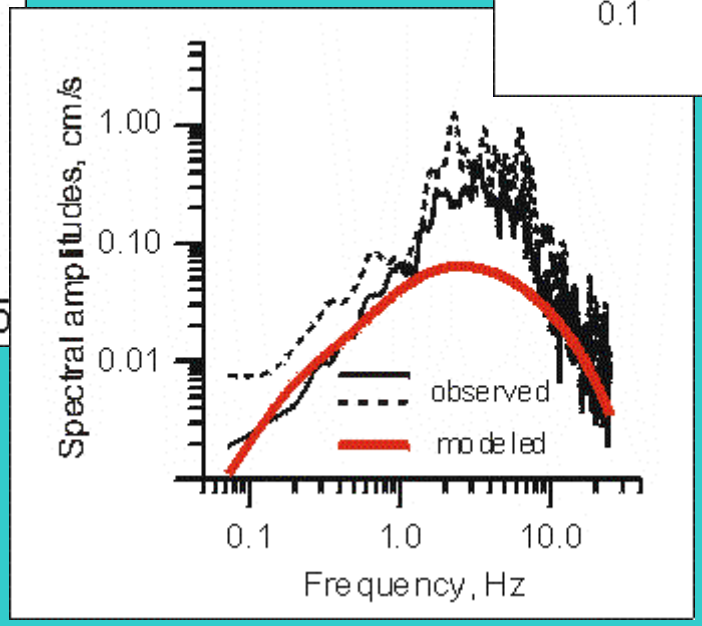
$$A(f) / VHR\,(f)$$

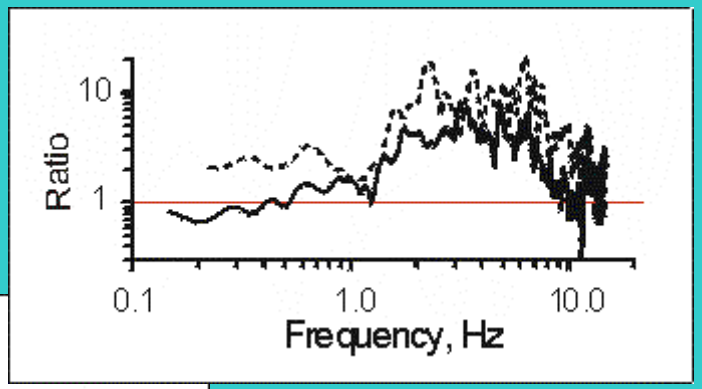
Site Effects
VHR-Model

Site Amplification

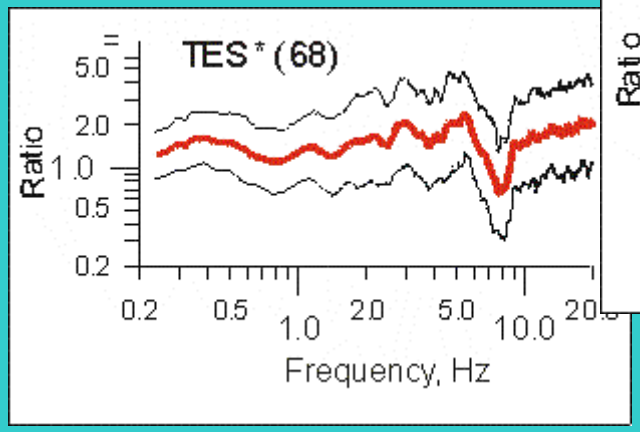
We considered site amplification as ratio between spectra of actual earthquake records (horizontal components) and those modeled for a hypothetical "**very hard rock**" (**VHR**) site. These are the so-called VHR Spectral Ratios.

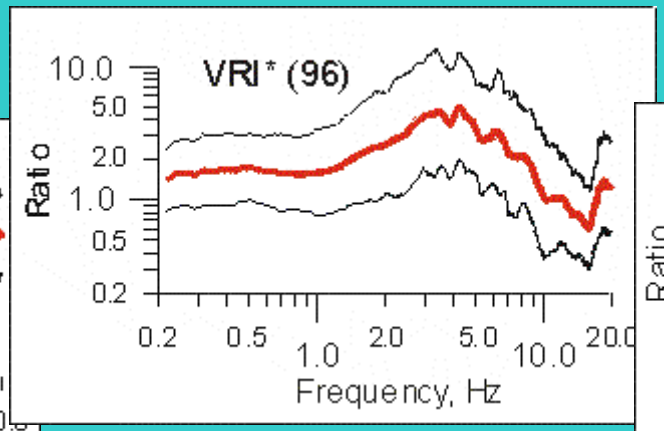


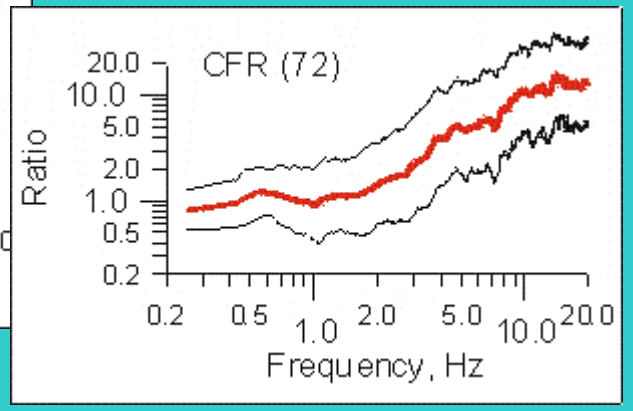




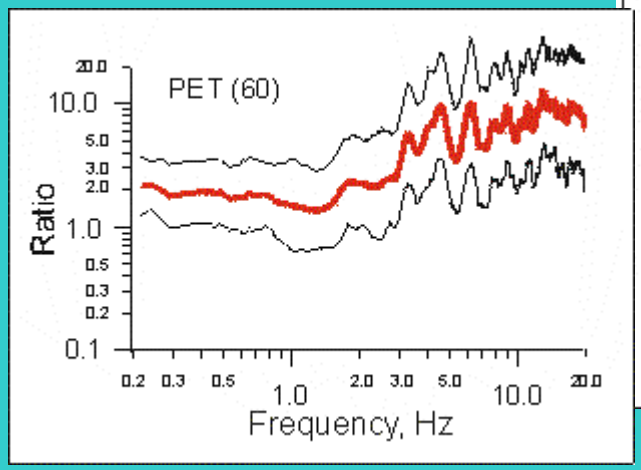
Rock sites

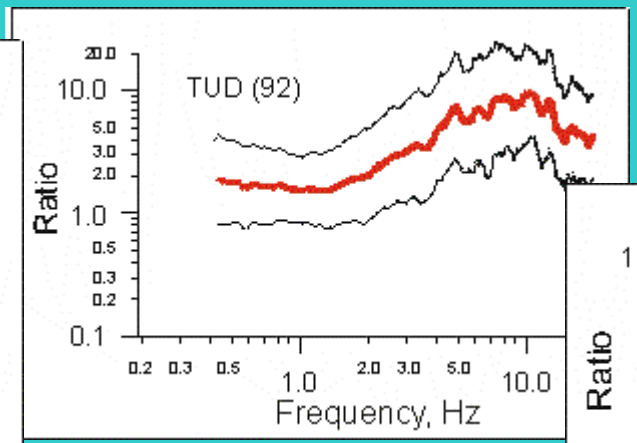


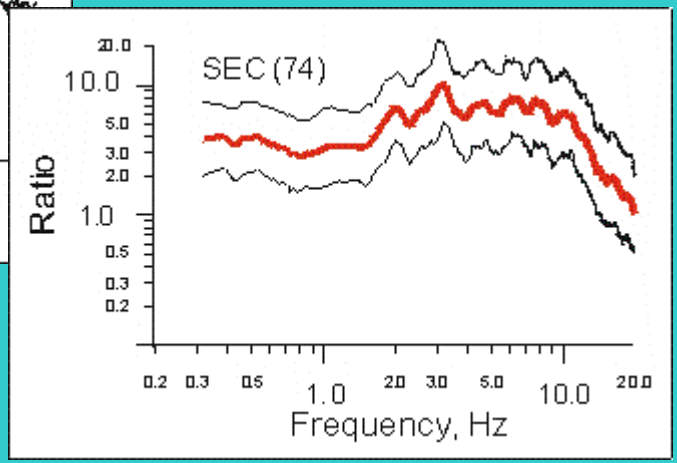




Soil sites

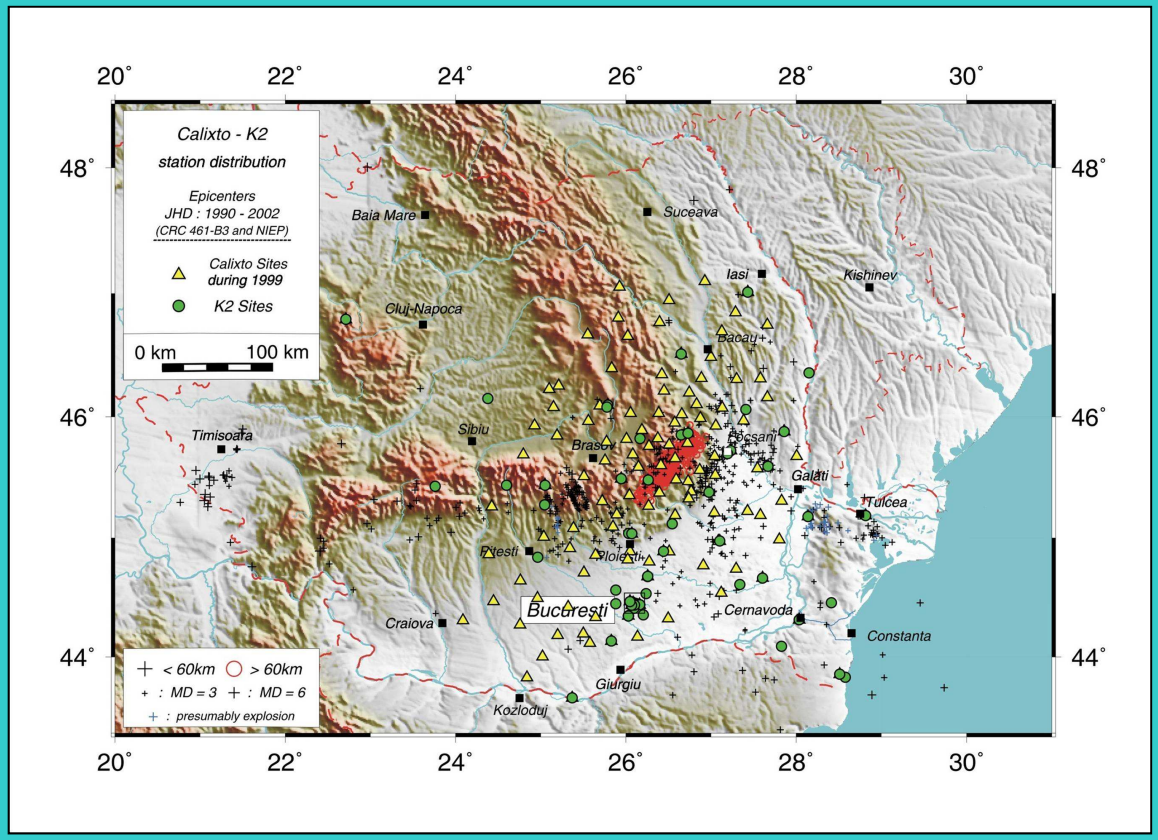






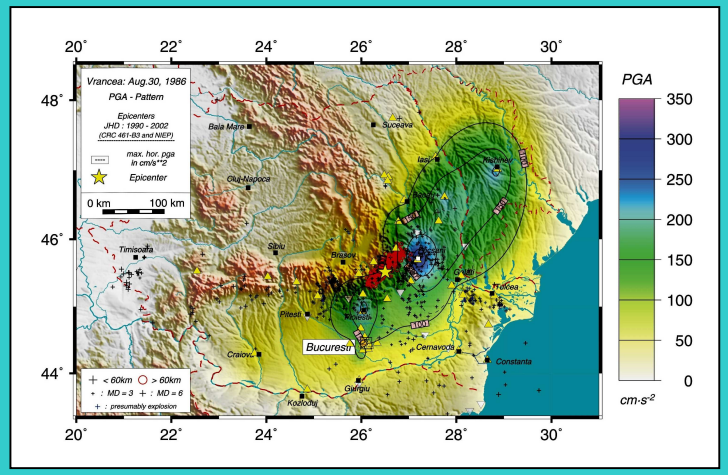
Site Effects

The database for the seismological evaluation of site characteristics (Grecu et al., 2004): about 120 Calixto sites and about 40 K2 sites.

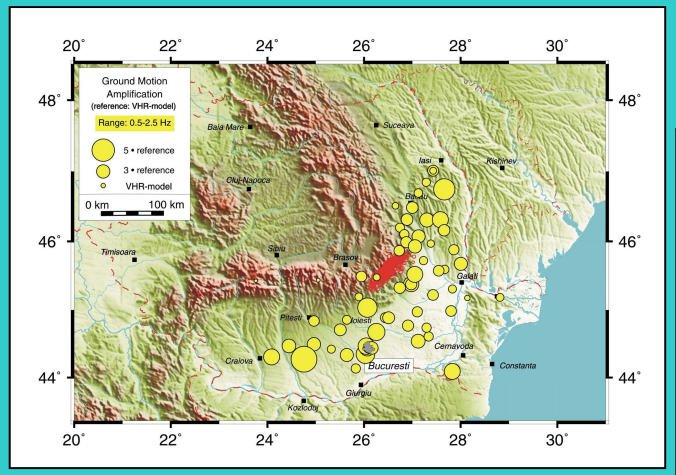


Site Effects

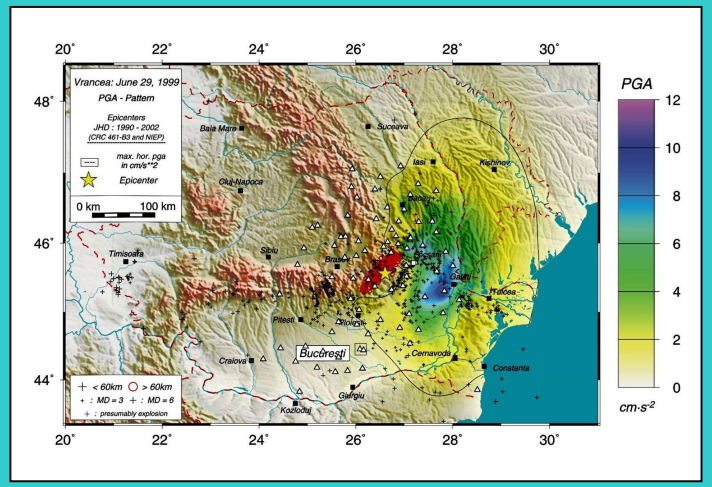
PGA – Shakemap of August 30, 1986 (Mw=7.2)



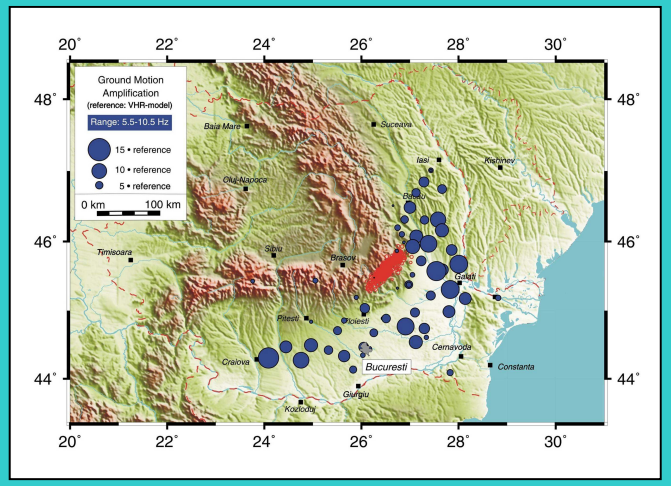
Average low-frequency soil-amplification



PGA – Shakemap of June 29, 1999 (Mw=4.2)



Average high-frequency soil-amplification



Results:

Ground motion is controlled by source and site effects.

Areas of strongest ground motion are up to 100km away from the epicenter.

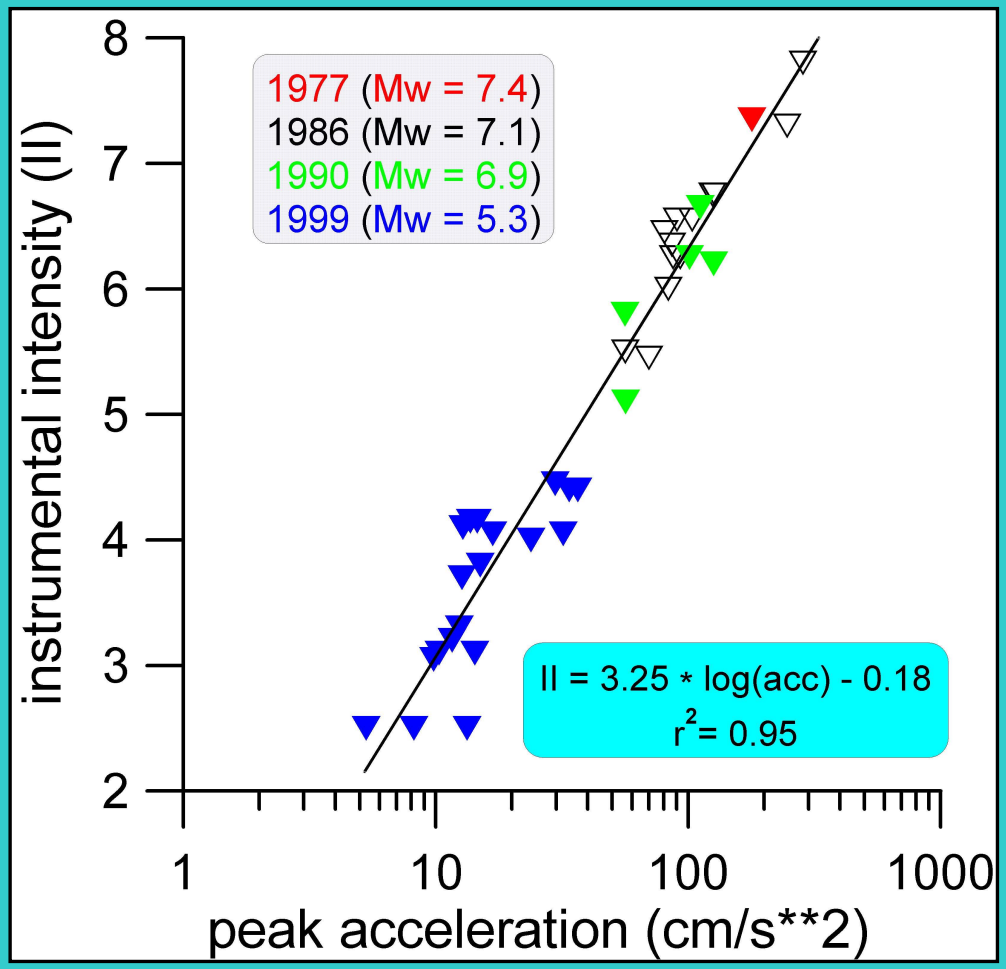
Only small amplification in the Carpathians, in both frequency ranges.

Maximum amplification in the Foredeeps is up to 5/15 times greater compared to reference.

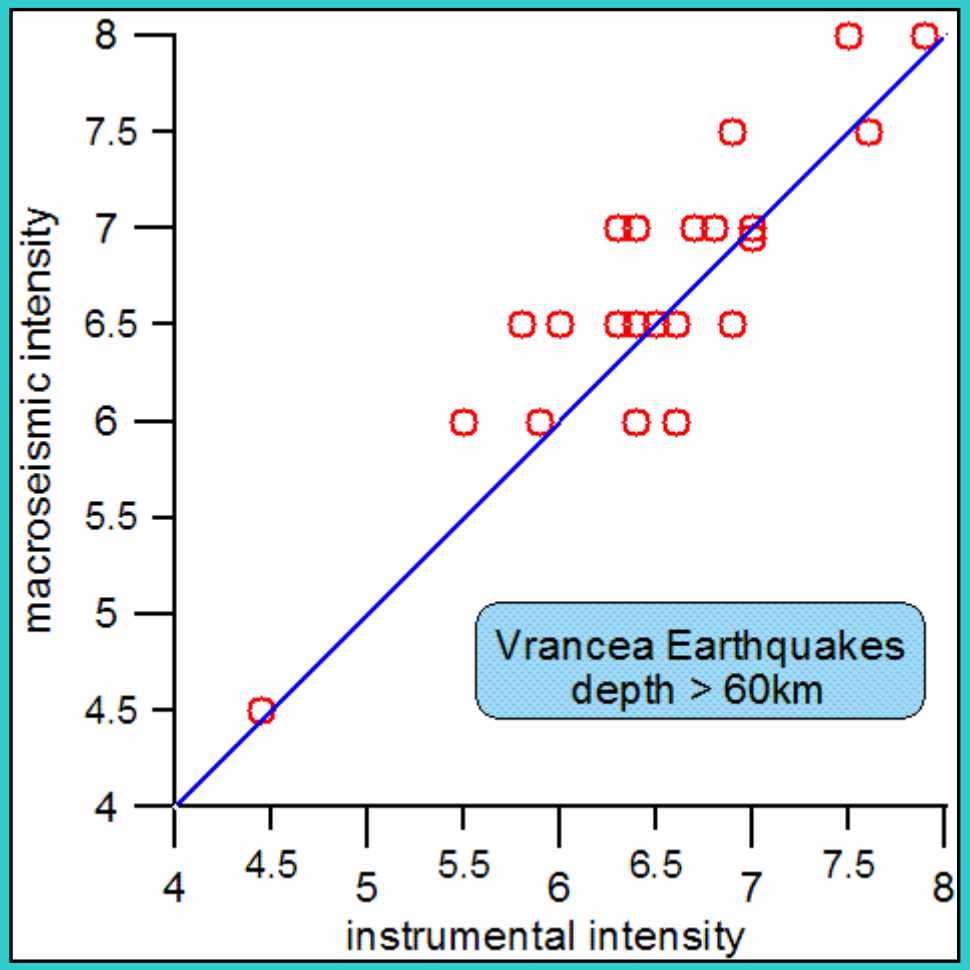
The Craiova area shows persistently high amplification.

High-frequency events will be amplified strongest in the eastern part of the Foredeeps.

Scaling relation for intermediate depth Vrancea earthquakes

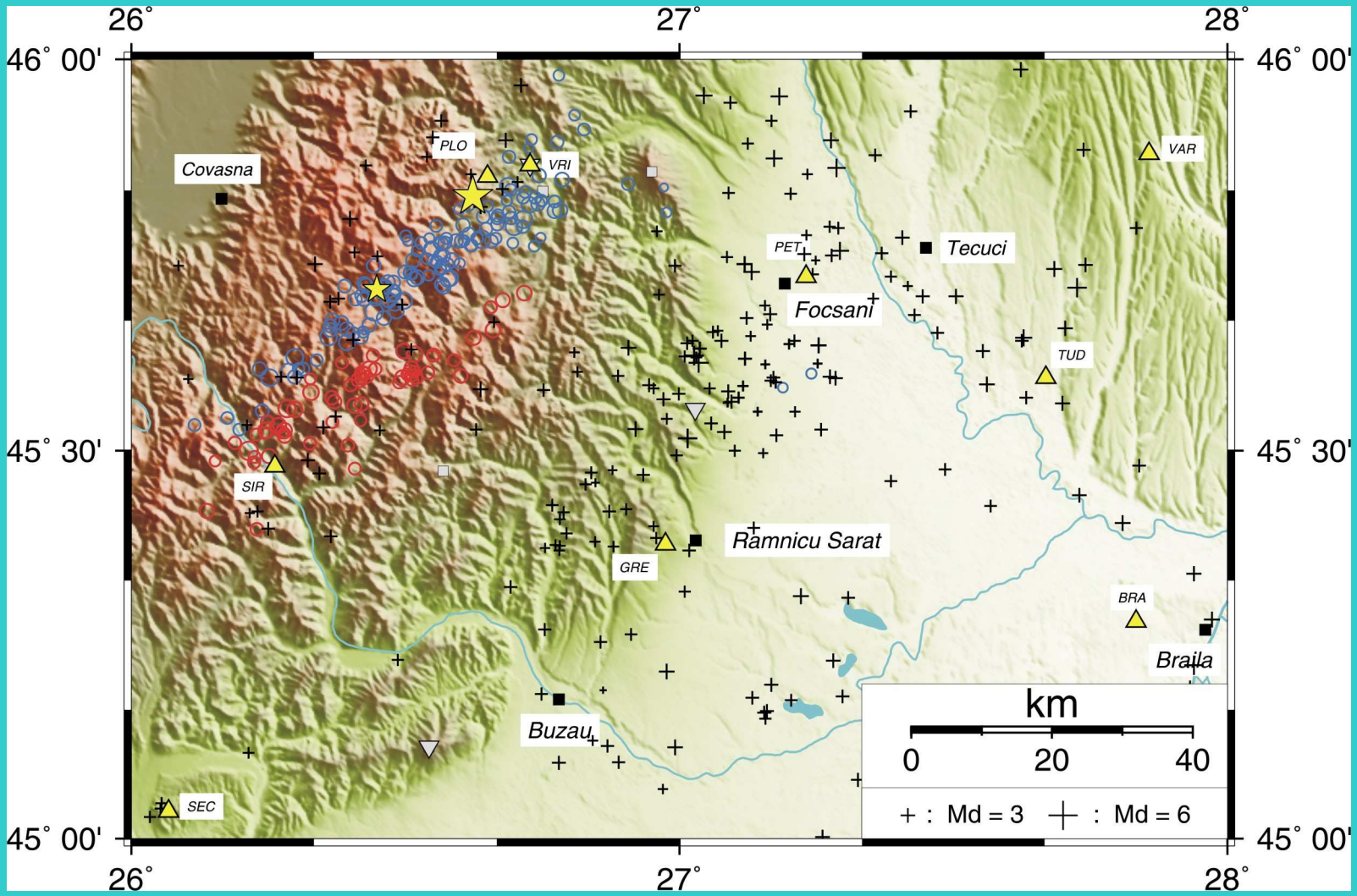


Comparison of instrumentally and macroseismically determined intensities

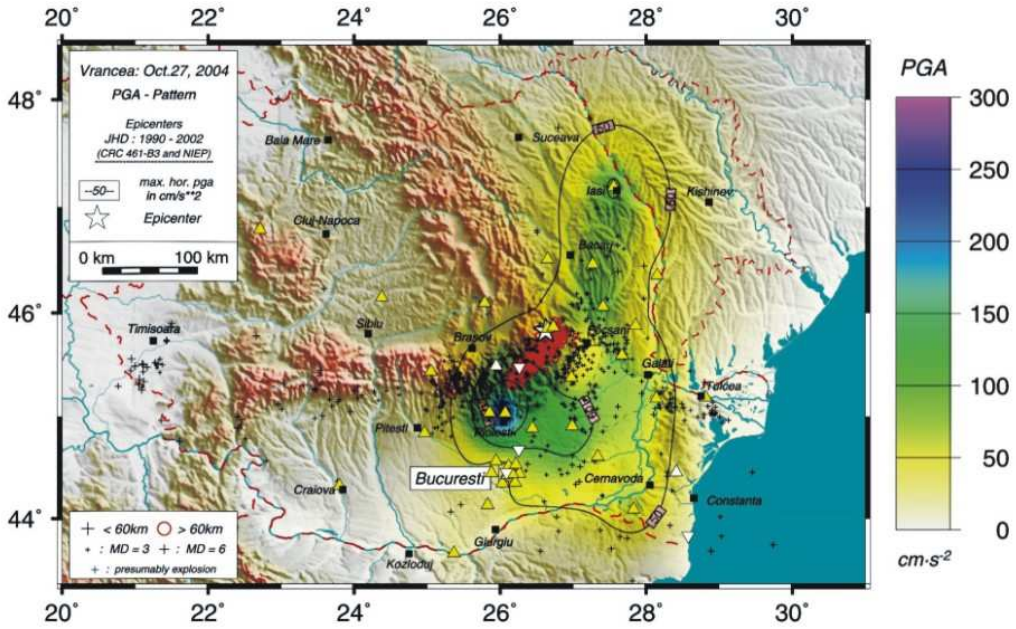


Gap of intensity data is filled by the October 27, 2004 event.

Determination of instrumentel intensities is done, but the macro-seismic information is still incomplete.


26°
27°
28°
46° 00'
45° 30'
45° 00'
Covasna
PLO
VRI
VAR
PET
Tecuci
Focsani
TUD
SIR
Ramnicu Sarat
GRE
BRA
Braila
Buzau
SEC
km
0
20
40
+ : Md = 3
: Md = 6

PGA - map of the Vrancea earthquake of October 27, 2004
depth = 100 km, Mw = 5.9



Similarities with the 1977 Mw=7.4 event:

nearly same hypocenter, depth, faultplane solution;

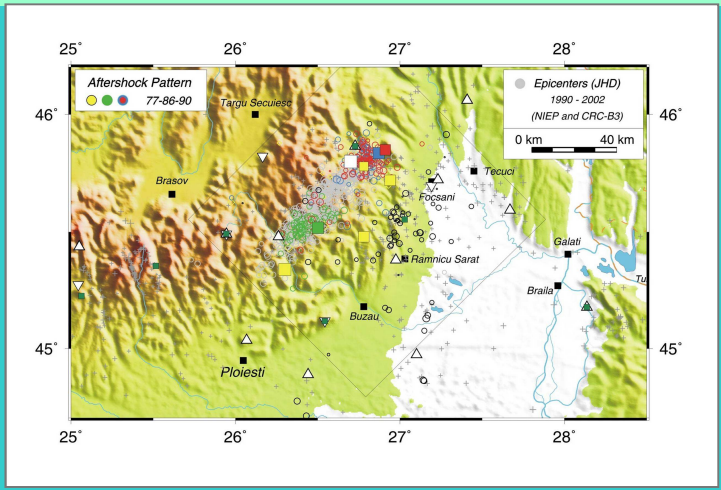
same area of strongest ground shaking about 50-100km apart from the hypocenter.

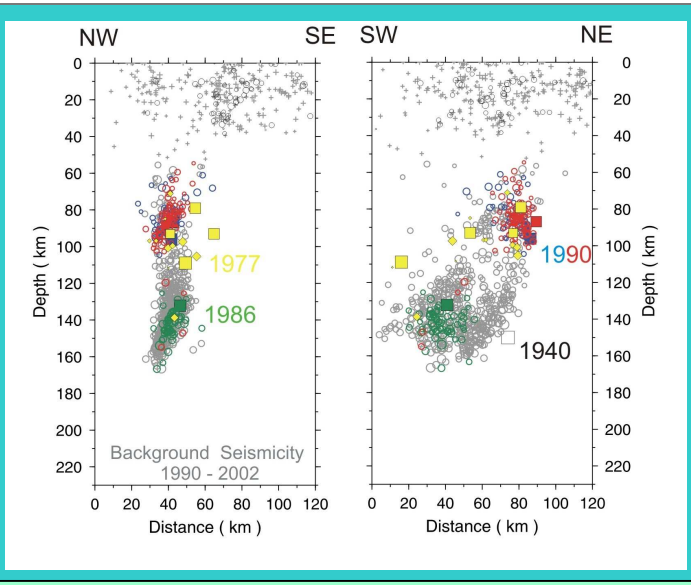
However, the 2004 event was a `simple` event, whereas the 1977 event has been considered by various authors as a multiple event propagating pre-dominantly southwest wards.

Problem: source complexity versus variation of deep structure ??????

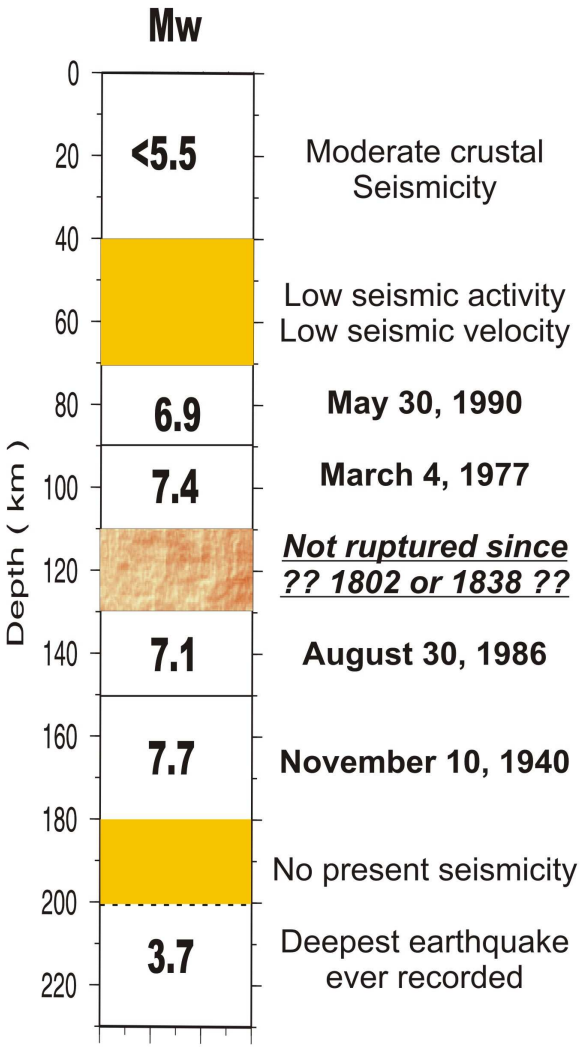
The Vrancea Source Zone

Geometry



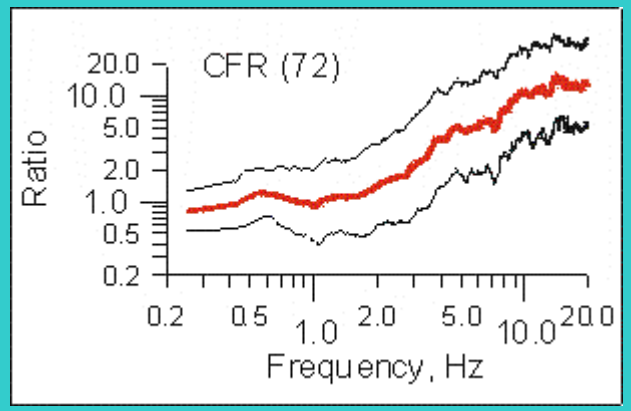


Oncescu and Trifu, 1987; Trifu et al., 1990; Oncescu and Bonjer, 1997; ….2005



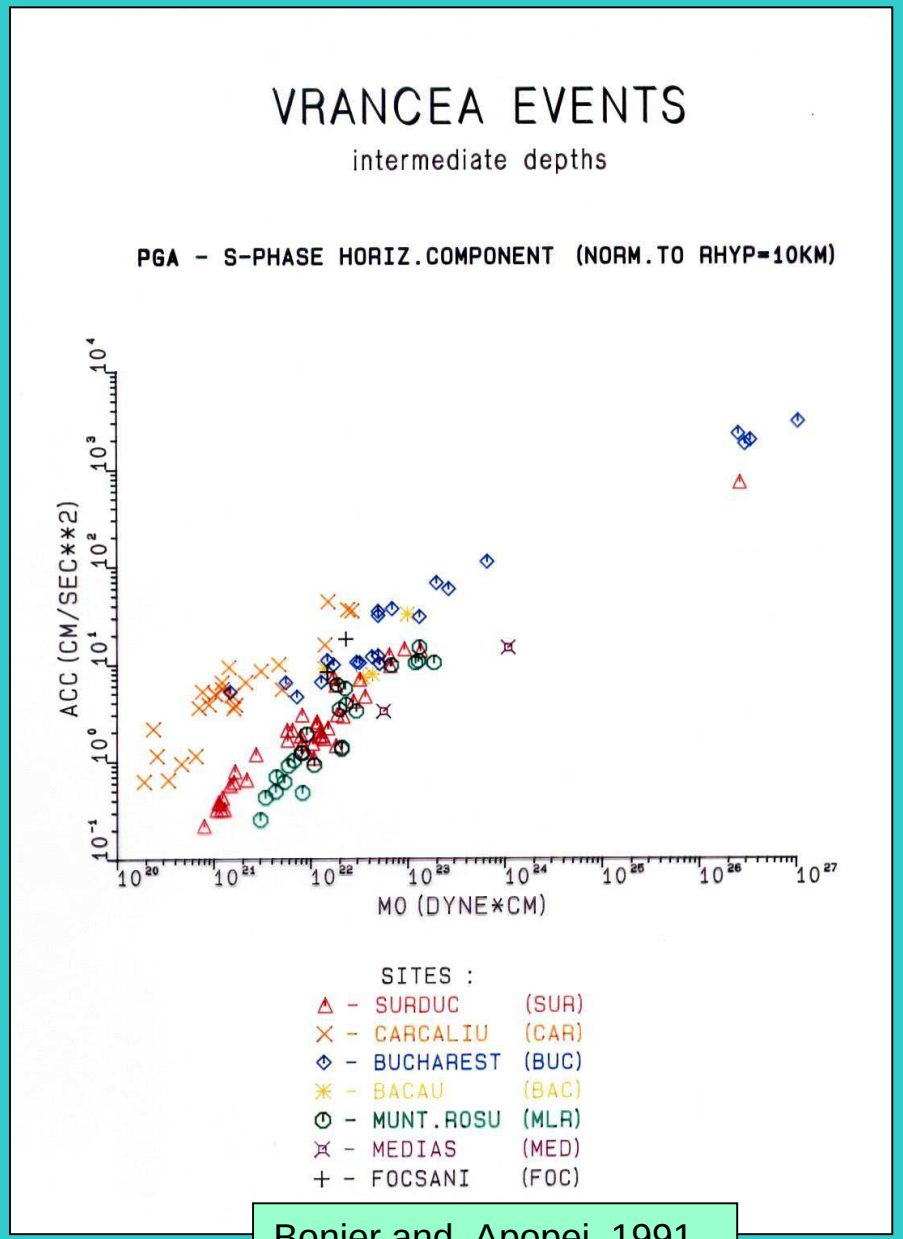
Oncescu and Bonjer, 1997

Site Effects



Site Amplification at Carcaliu

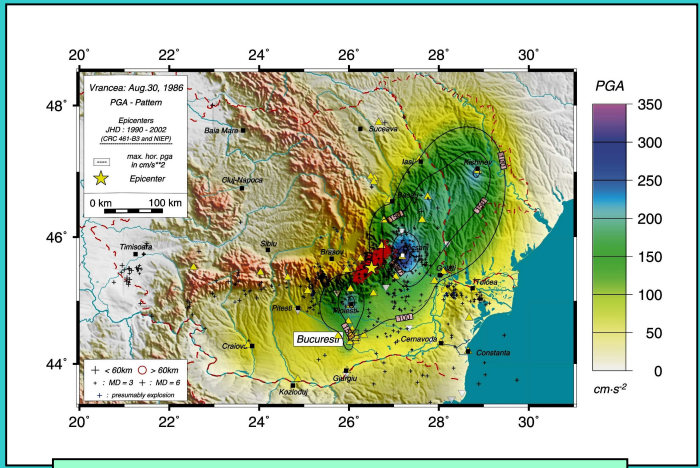
(Grecu et al., 2004)



Bonjer and, Apopei, 1991

Site Effects

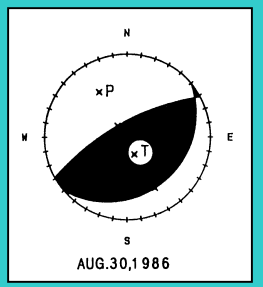
The August 30, 1986 VRANCEA Event : Source- and Site-Effects

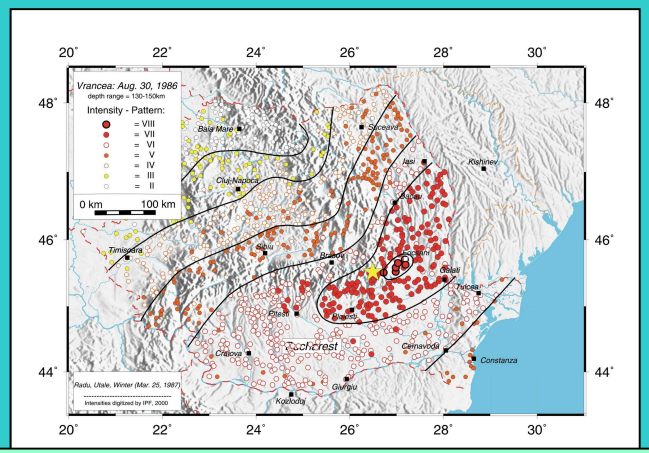


PGA-Shakemap (max. horiz components taken from Radu et al.,1992)

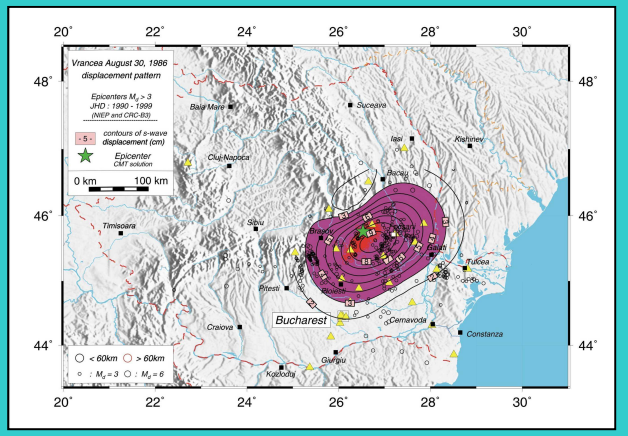
Max. peak acceleration: 319 cm/s^2 (Focsani)

Max. intensity (MSK): VIII (Focsani)





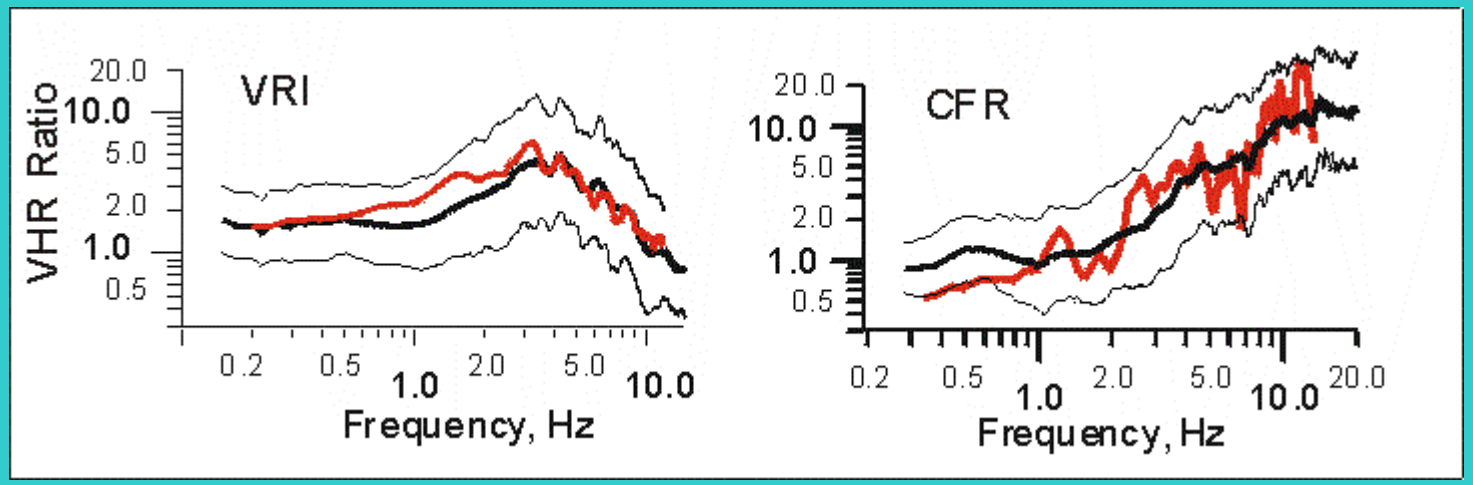
Macroseismic Intensity Pattern (Radu et al., 1987)



Radiation pattern, corrected for propagation effects calculated with ' Kiniso ' (Oncescu,1997).

Does the VHR ratio properly reflect the site response during strong earthquakes, when it is evaluated from records of small earthquakes?

Where ever possible, we compared the site amplification characteristics obtained from both, small and large earthquakes



<u>Rock stations</u>: mean amplitude amplification

(black lines - small events; **red lines** - large events)

PGA - map of the Vrancea earthquake of October 27, 2004
depth = 100 km, Mw = 5.9