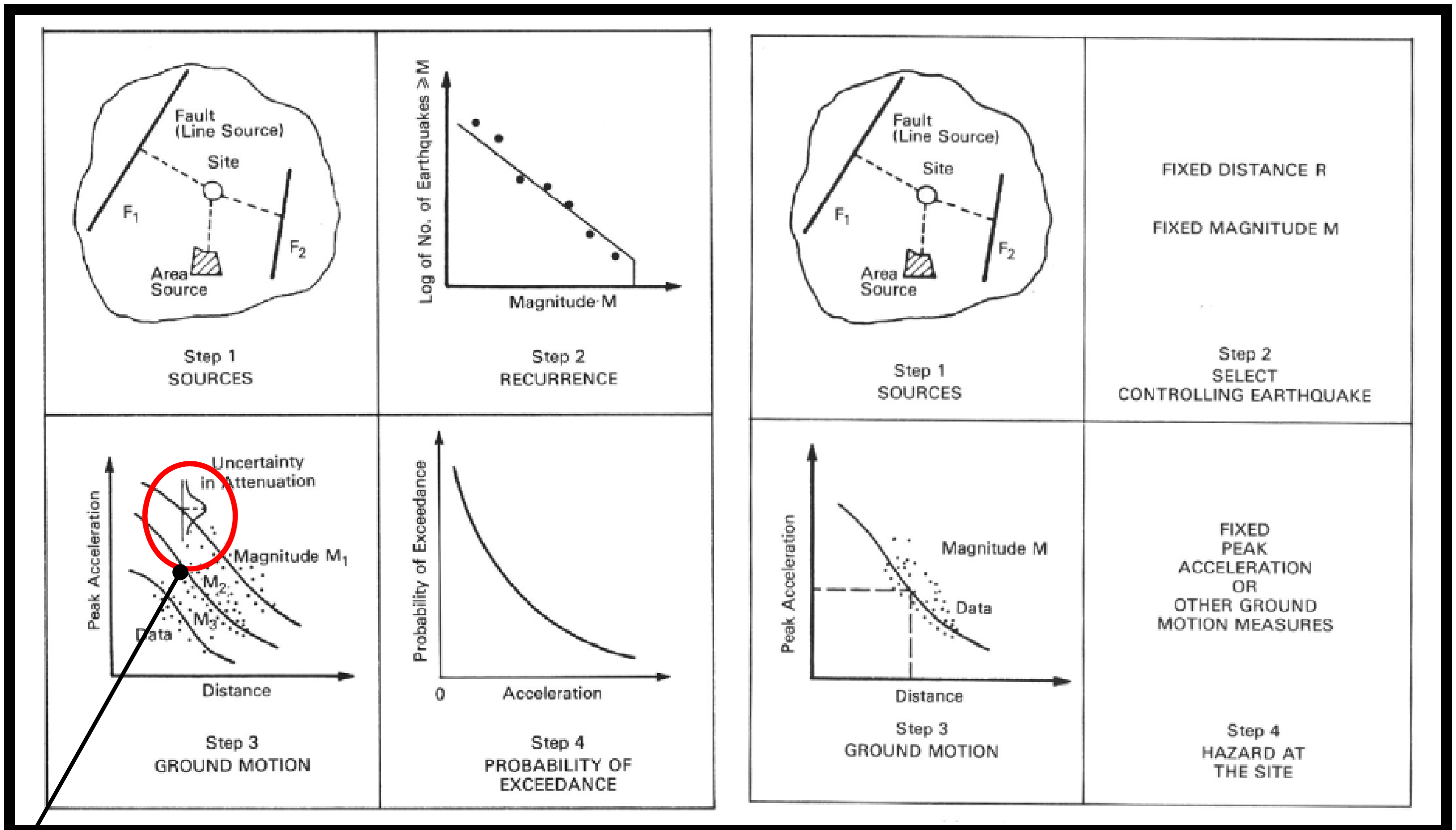
SEISMIC HAZARD
Experiences

I.T.S.A.K. CONTRIBUTION

MARGARIS Basil margaris@itsak.gr
PAPAIOANNOU Christos chpapai@itsak.gr

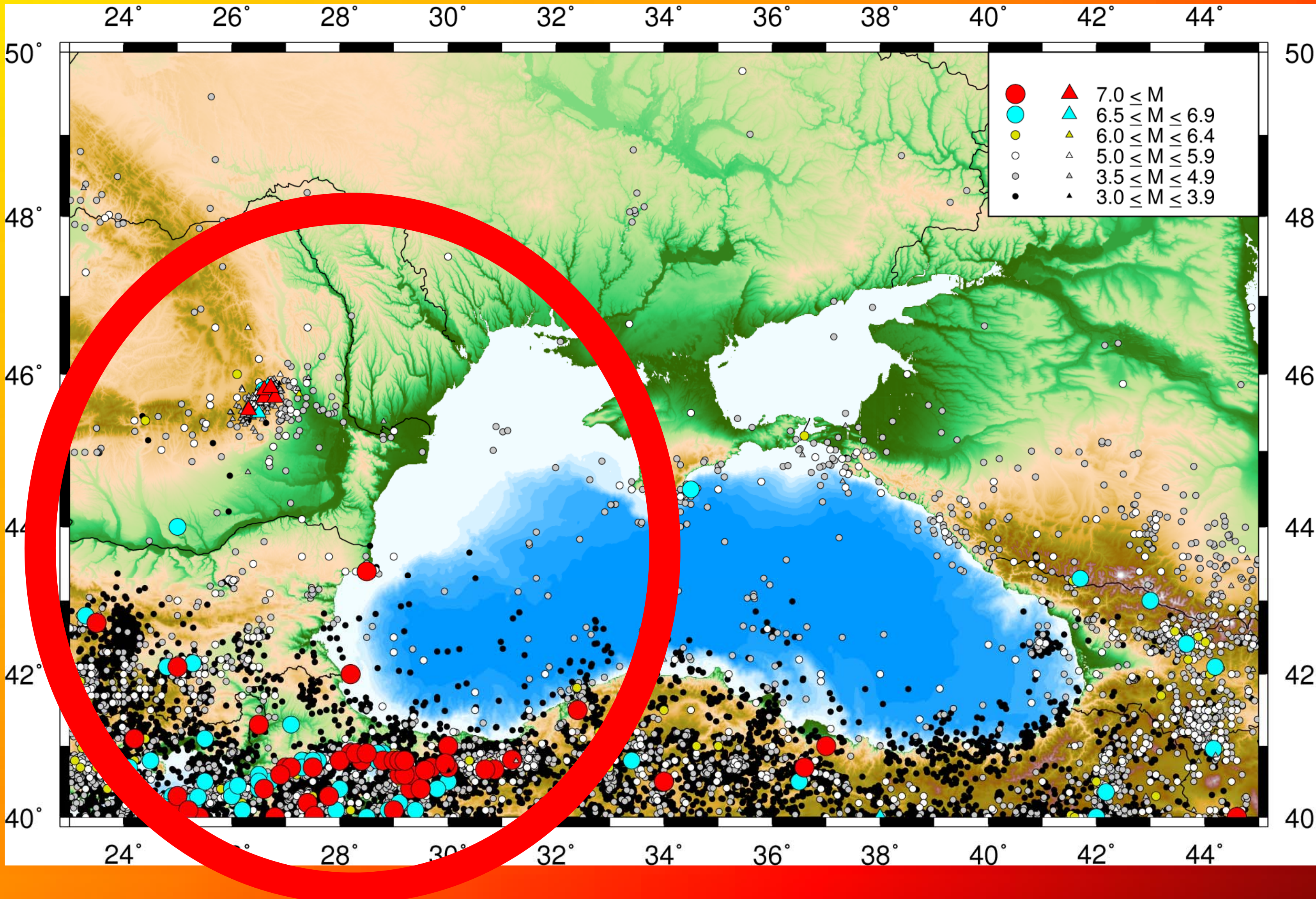
BASIC ELEMENTS OF SEISMIC HAZARD

PSHA vs. DSHA



Do not forget S.I.G.M.A.

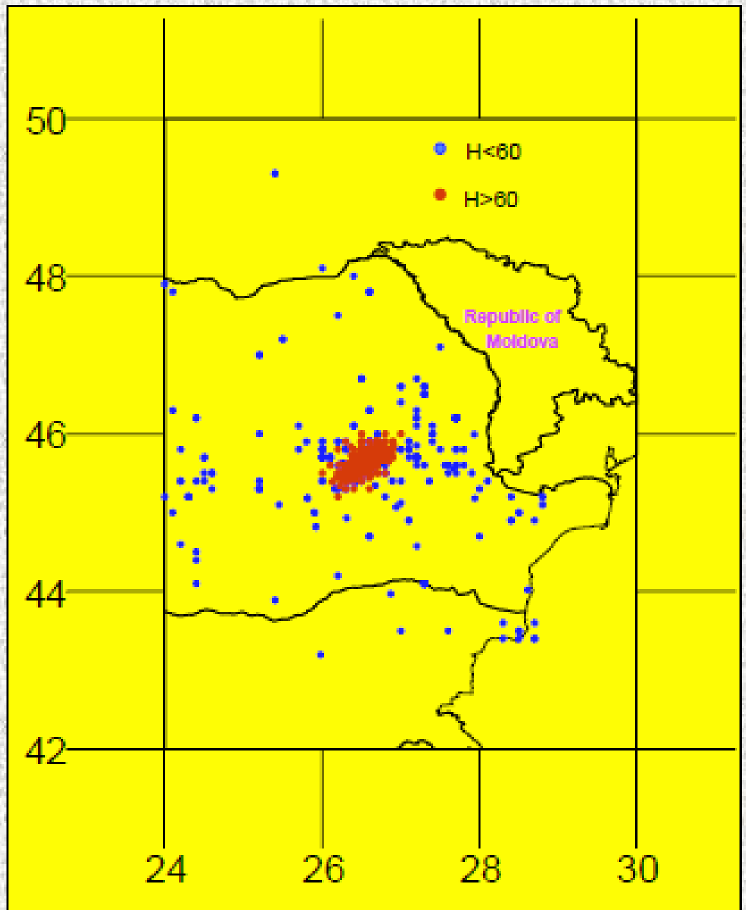
Scatter In Ground Motion Attenuation

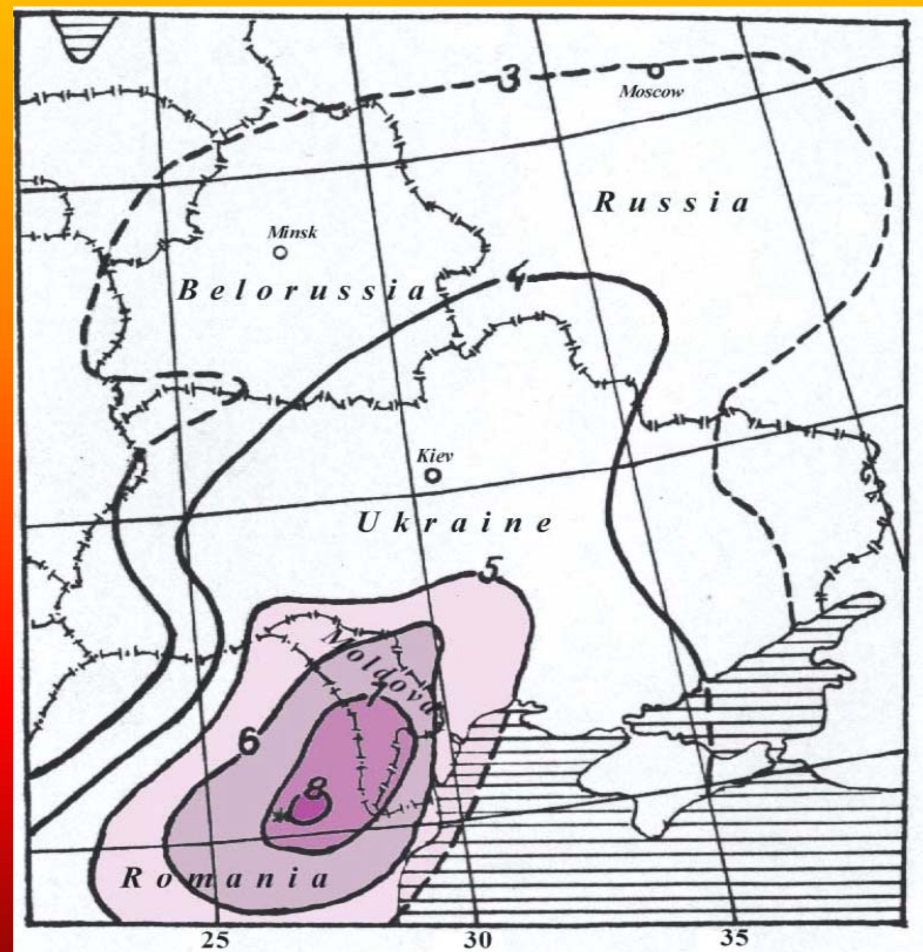


Seismicity map of Black Sea and Surroundings

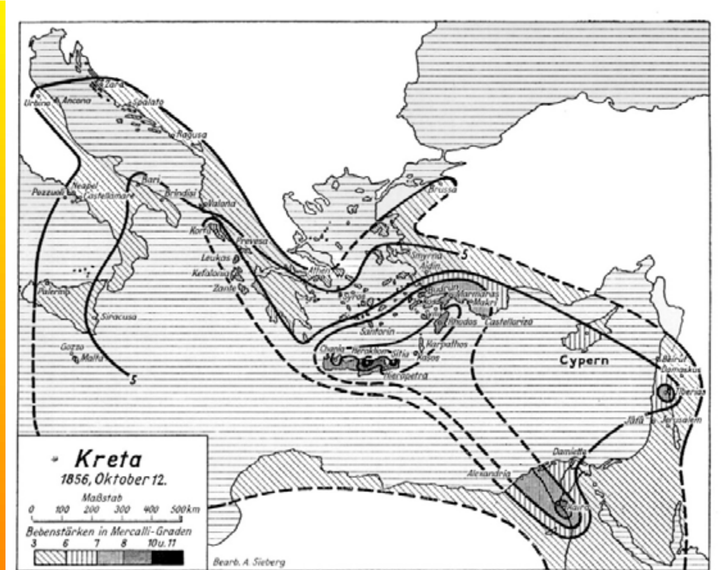
VASILE ALCAZ & ION APOSTOL

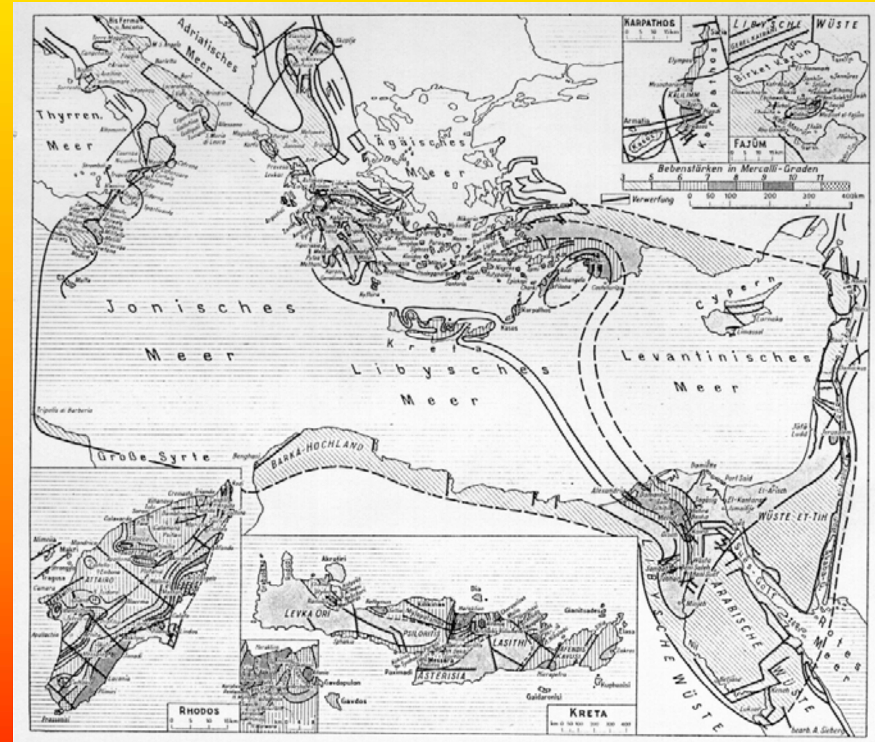
Earthquake Epicenter Around
Republic of Moldova, 1500-20 (M >4)

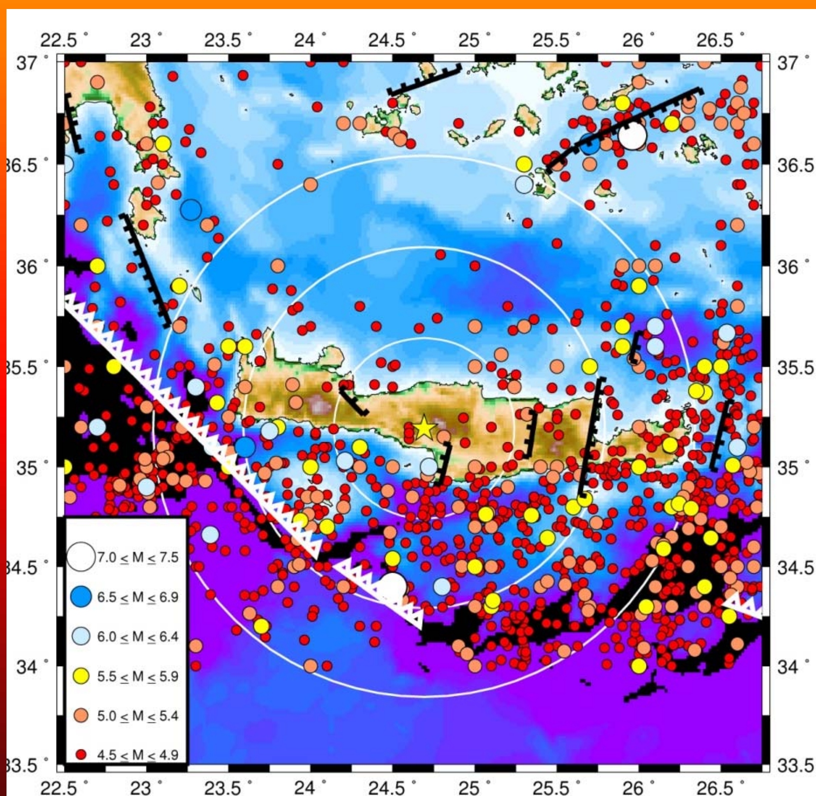


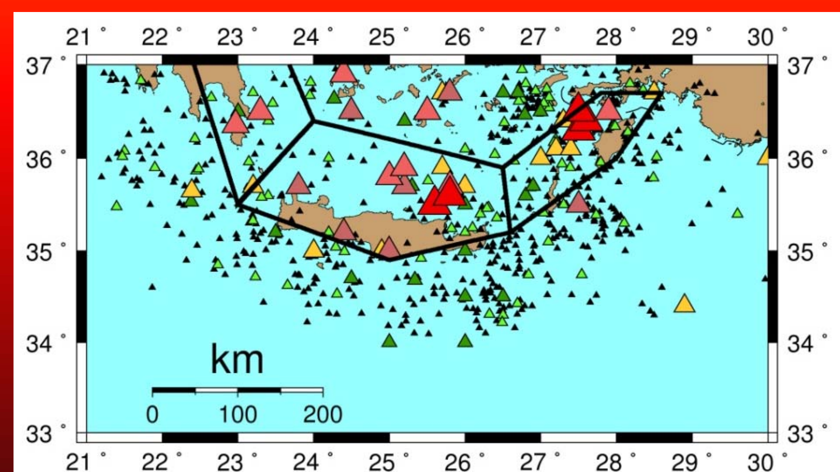


NO EQS IN THE AREA OF MOLDOVA !!


Kreta
1856, Oktober 12.
Maßstab
0 100 200 300 400 500km
Bebenstärken in Mercalli-Graden
3 6 7 8 10u.11
Cypern
Bearb. A. Sieberg

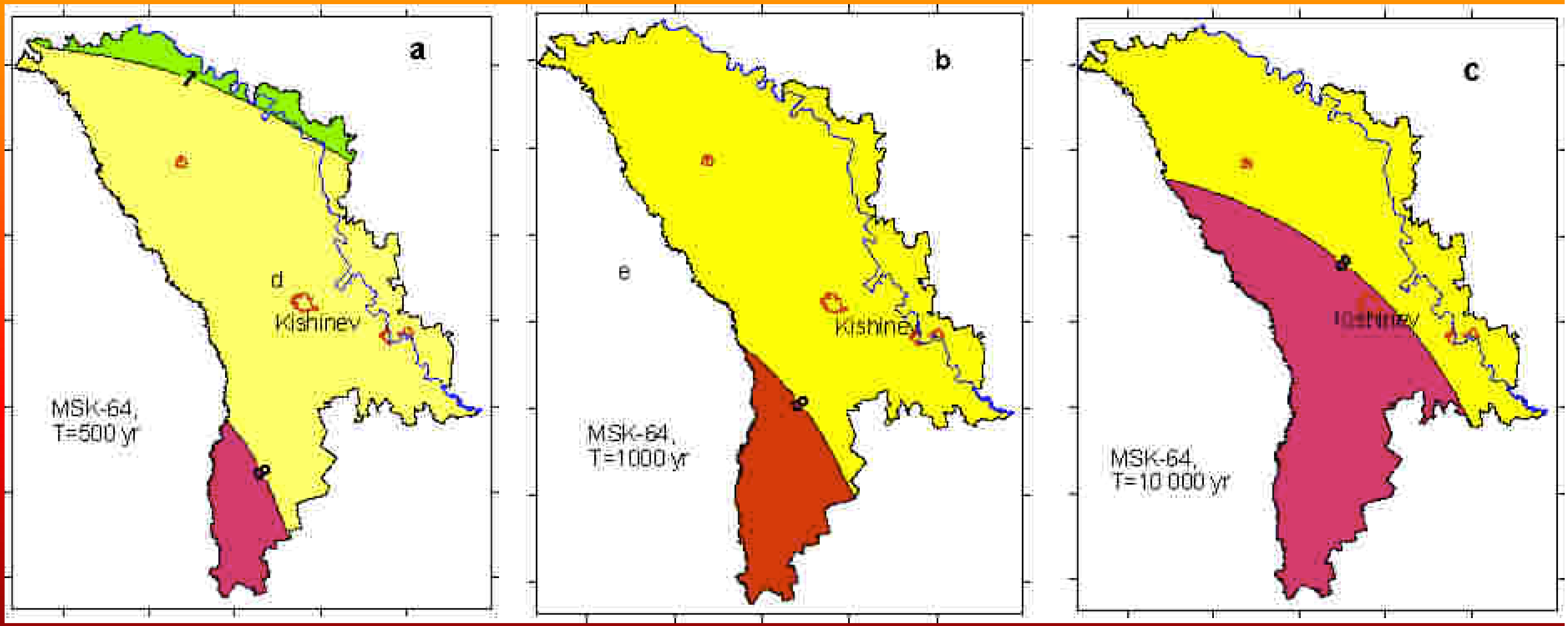

Adriatisches Meer
Thyrren. Meer
Ägäisches Meer
Jonisches Meer
Libysches Meer
Levantinisches Meer
Cypern
Große Syrte
Barka-Hochland
Karpathos
Fajûm
Wüste
Bebenstärken in Mercalli-Graden
Verwerfung
Rhodos
Kreta
Levka Ori
Arabische Wüste


22.5° 23° 23.5° 24° 24.5° 25° 25.5° 26° 26.5°
37° 36.5° 36° 35.5° 35° 34.5° 34° 33.5°
7.0 ≤ M ≤ 7.5
6.5 ≤ M ≤ 6.9
6.0 ≤ M ≤ 6.4
5.5 ≤ M ≤ 5.9
5.0 ≤ M ≤ 5.4
4.5 ≤ M ≤ 4.9


21° 22° 23° 24° 25° 26° 27° 28° 29° 30°
37° 36° 35° 34° 33°
km
0 100 200

Earthquake hazard maps from subcrustal Vrancea zone for 500, 1000, and 10 000 years return periods

MACROSEISMIC INTENSITIES



VASILE ALCAZ & ION APOSTOL

Project funded by the EUROPEAN UNION

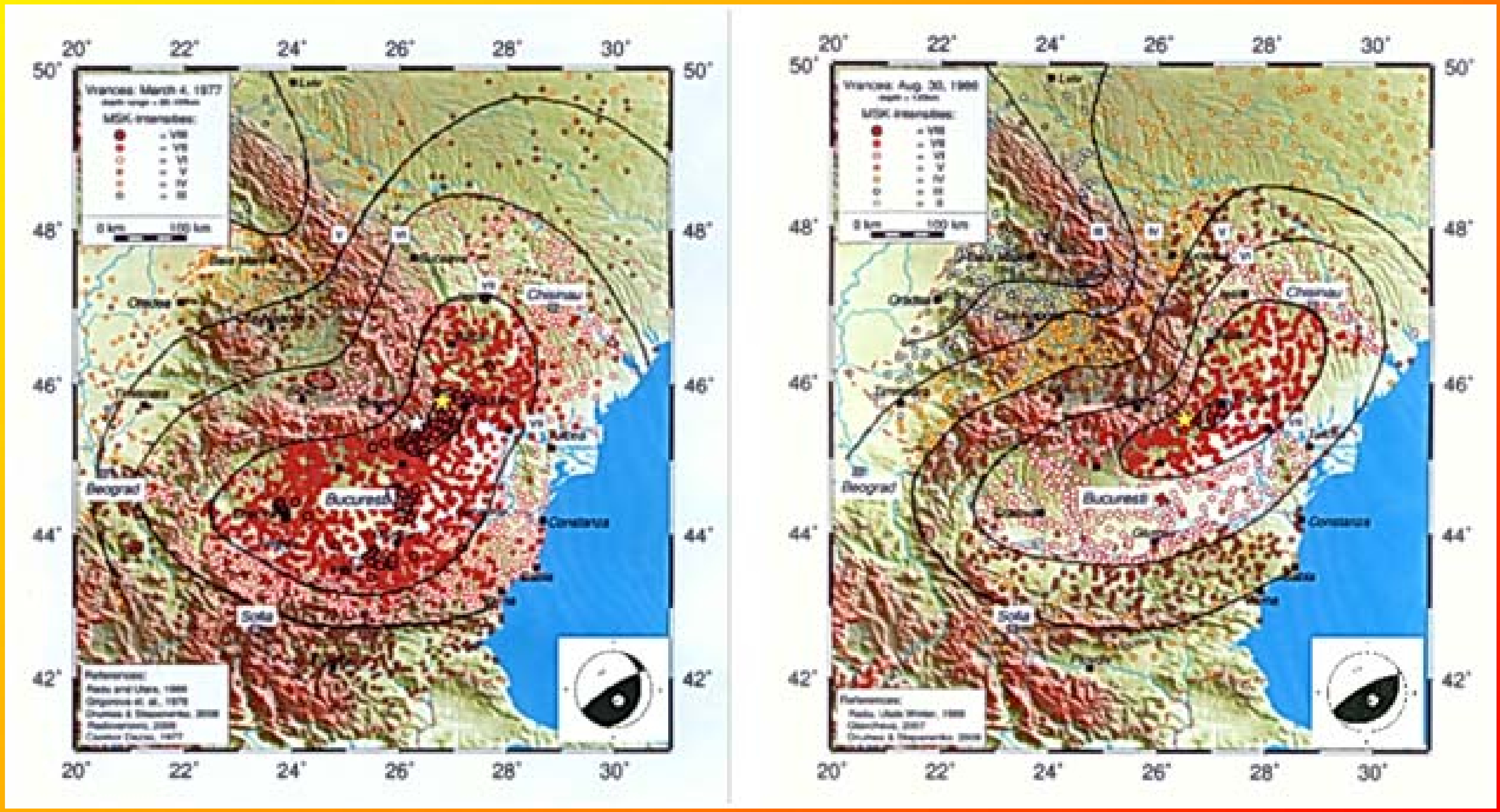
SciNet NatHaz

Black Sea Cross Border Cooperation

Republic of Moldova:
Damage Losses From March 4, 1977 And August 31, 1986 Seismic Events

Type of construction	**Total analysed (Number of buildings)**		**Severely damaged, need reconstruction**		**Completely destroyed**	
	1977	*1986*	*1977*	*1986*	*1977*	*1986*
State-owned dwellings	2821	7000	1449	1152	1372	757
Private dwellings	6984	49000	6096	4820	888	-
Schools	334	546	263	128	71	26
Pre-schooler institutions	188	562	141	88	47	33
Health care institutions	181	353	126	64	55	39
Cultural institutions	238	262	161	189	77	73
Commercial institutions	314	326	110	105	34	221
Other institutions	789	489	568	469	221	20
Total	**11849**	**58538**	**8914**	**7015**	**2765**	**1169**

VASILE ALCAZ & ION APOSTOL



Unified macroseismic maps in MSK scale of the Vrancea events of 1977 (Mw=7.5, H=83km) and 1986 (Mw=7.2, H=132km).
(Radu et al., 1987: Bonjer 2013 mod.).

Notice the pattern of the macroseismic field of both events

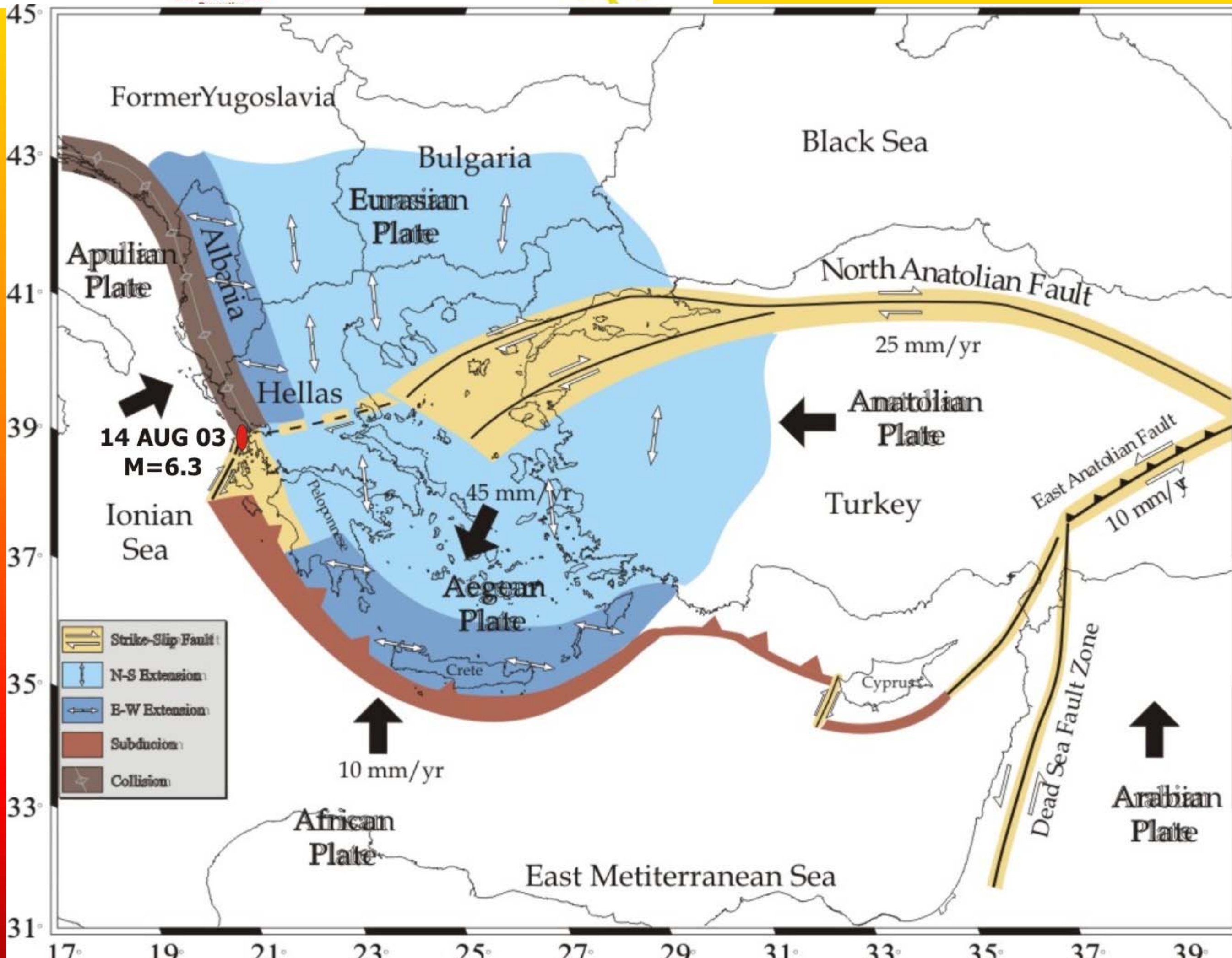
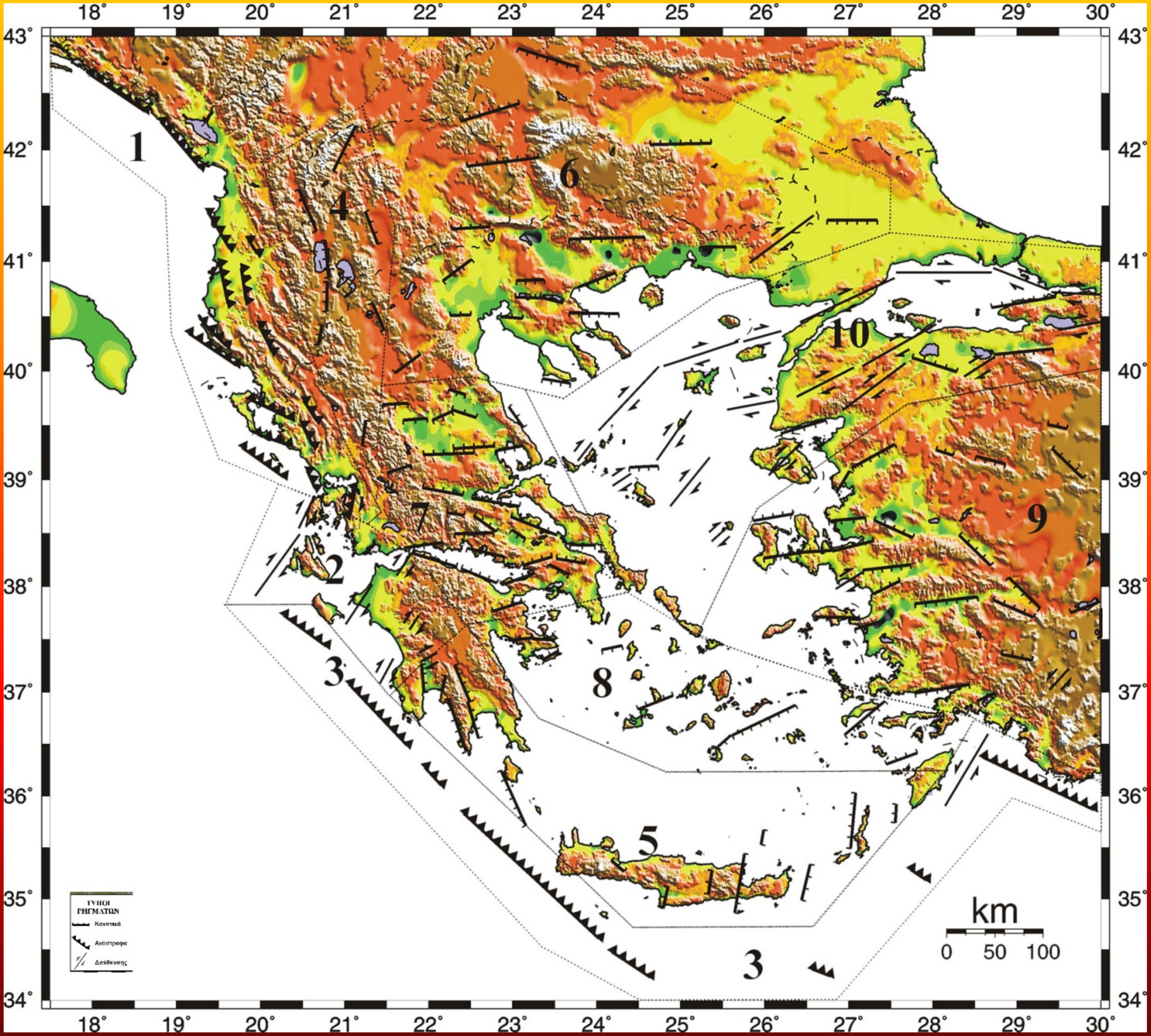
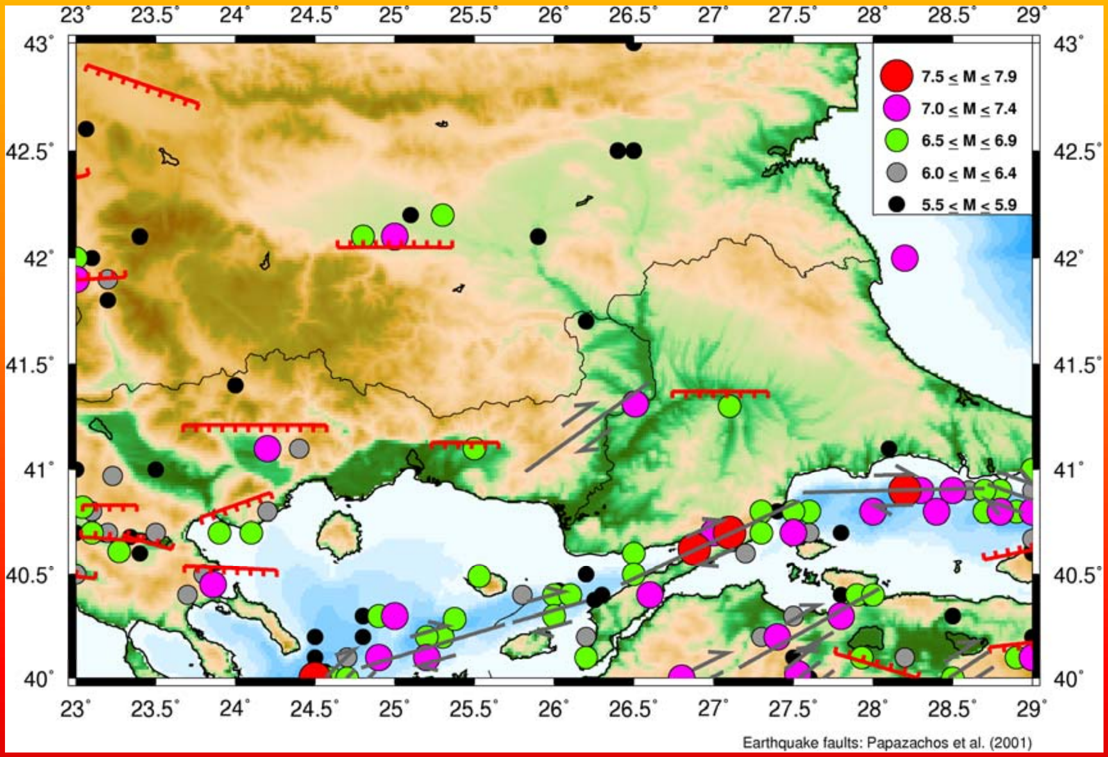


Plate Motions



Faults of strong earthquakes in the Aegean area since 550BC

(Papazachos et al., 2001)



STRONG HISTORICAL EARTHQUAKES

Papazachos and Papazachou (1997, 2003)

LOW SEISMICITY REGION
HOWEVER STRONG (M≥7.0) OCCURRED SINCE ANTIQUITY

TWO models of seismic sources

PAPAIOANNOU (2006)

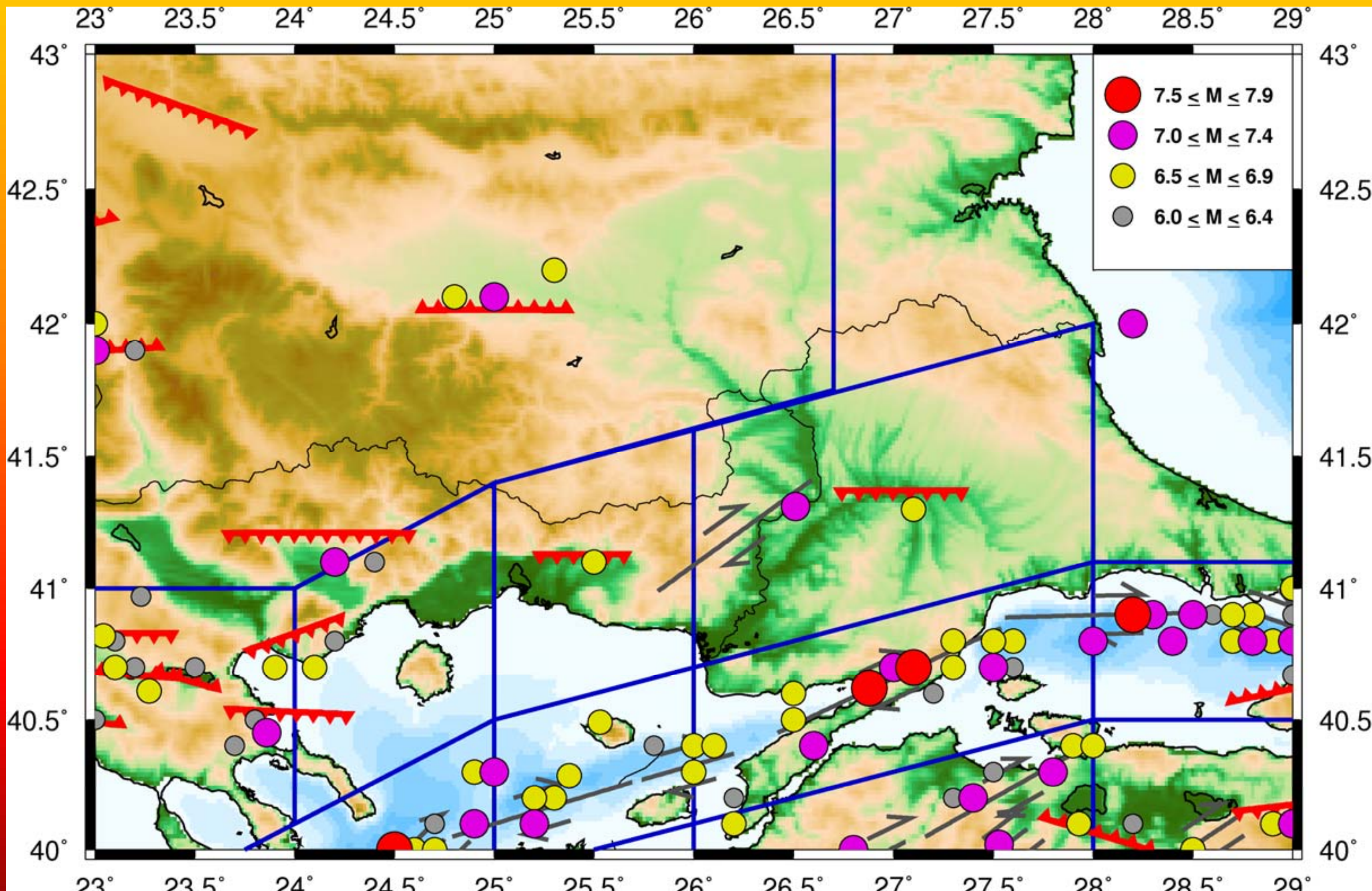
USED FOR THE REVISION OF THE S.H. MAP OF GREECE

CONSISTS OF FAULTS (FOR THE M≥6.0 EQS) &

AREA TYPE SOURCES OF EQS. WITH 4.0 ≤ M ≤ 5.9

Papaioannou & Papazachos (:BSSA 2000)

AREA TYPE SOURCES OF SHALLOW EQS. ONLY

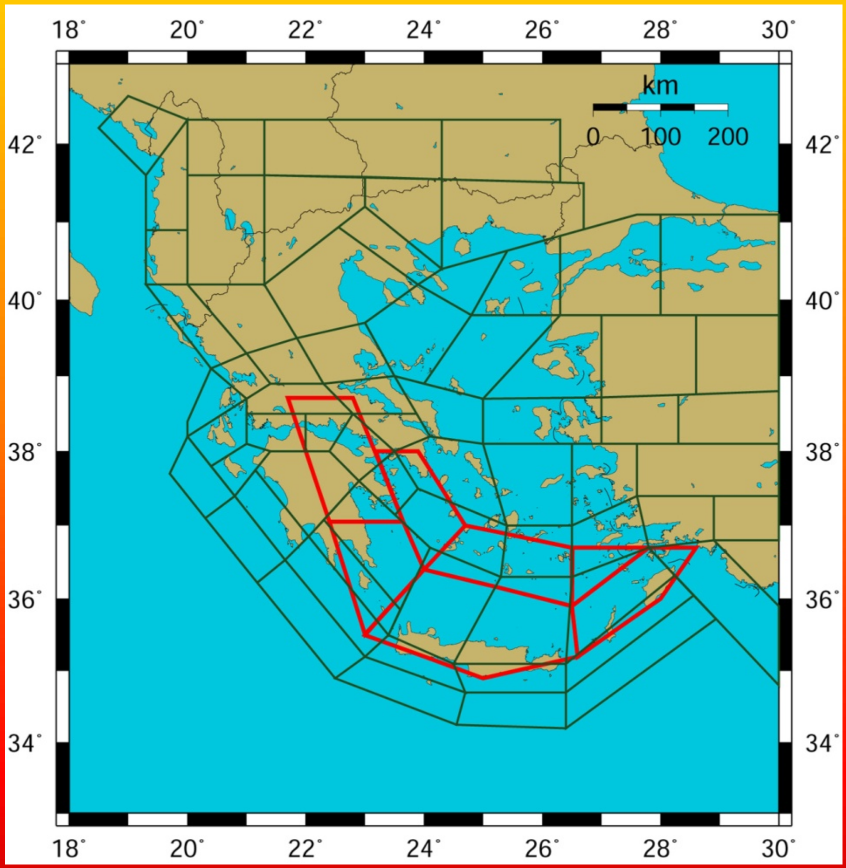


7.5 ≤ M ≤ 7.9
7.0 ≤ M ≤ 7.4
6.5 ≤ M ≤ 6.9
6.0 ≤ M ≤ 6.4

Project funded by the EUROPEAN UNION

SciNet NatHaz Prevention

Black Sea CROSS BORDER COOPERATION



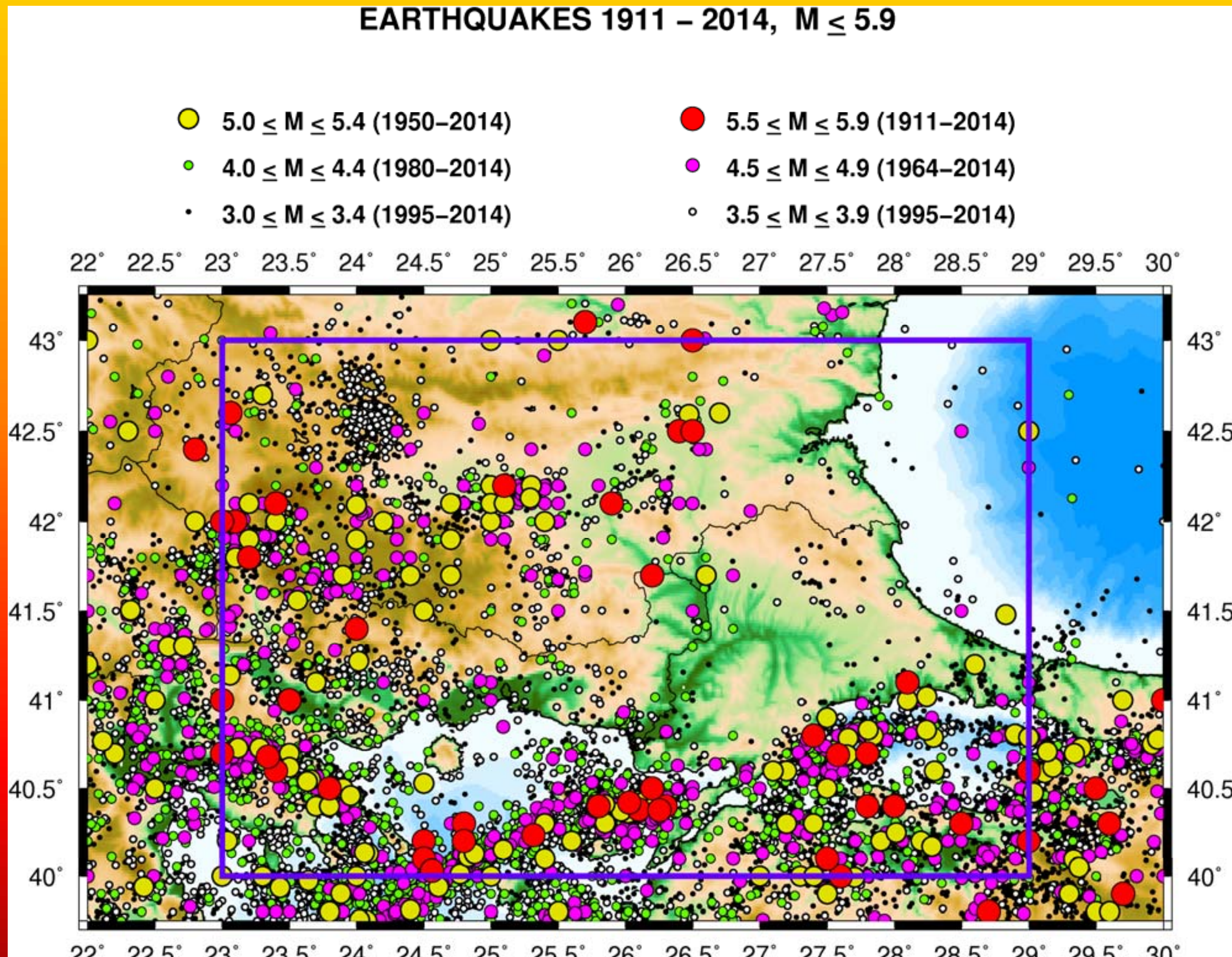
PAPAIOANNOU & PAPAZACHOS (:BSSA 2000)

PAPAIOANNOU (ECEES 2006)

Project funded by the EUROPEAN UNION

SciNet NatHaz

Black Sea CROSS BORDER COOPERATION



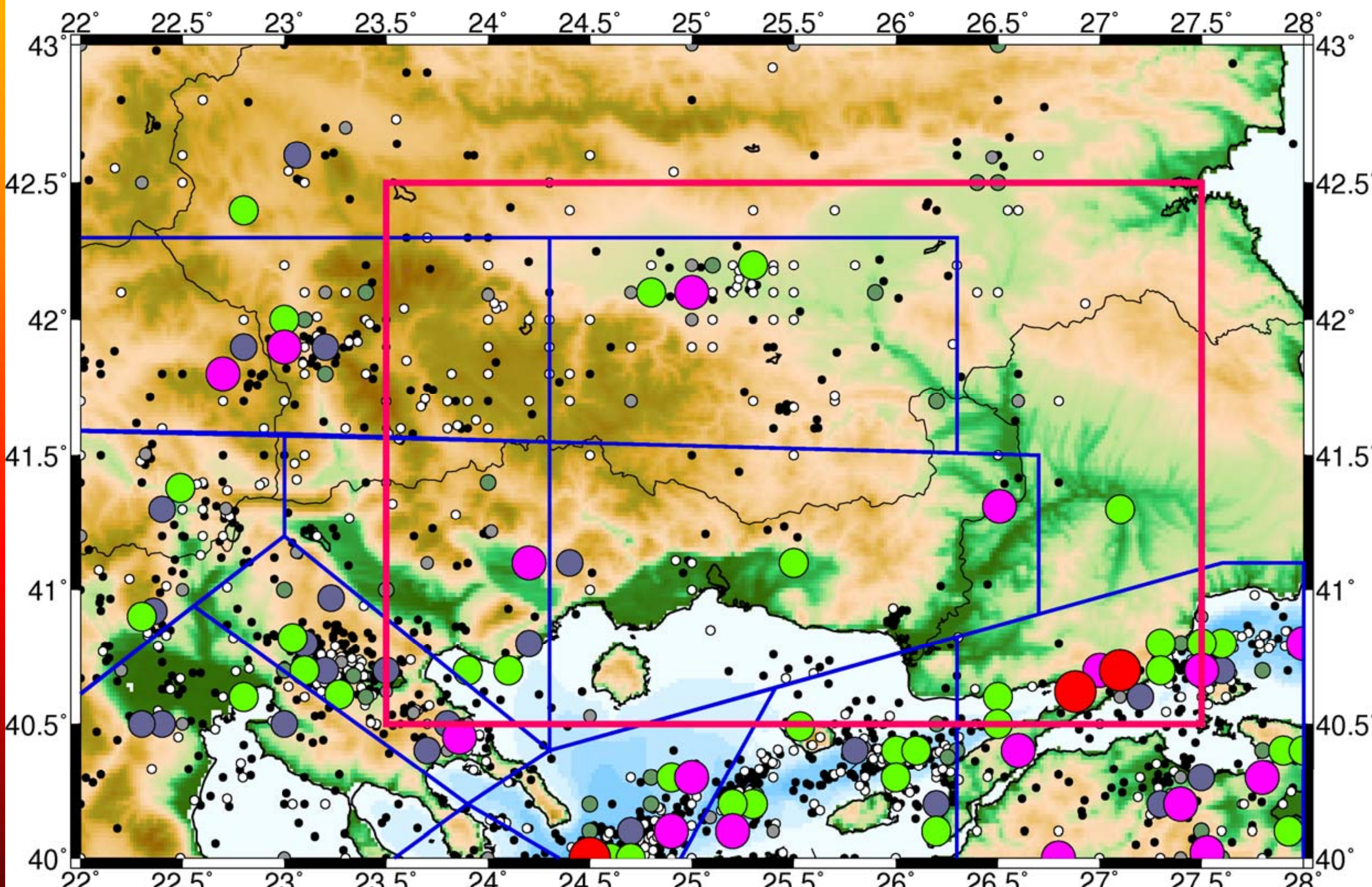
LOW SEISMICITY REGION WITH ACTIVITY OF SMALL -MEDIUM SIZE EVENTS

Project funded by the EUROPEAN UNION

SciNet NatHaz Prevention

Black Sea CROSS BORDER COOPERATION

Model of Area Sources (BSSA 2000)



MACROSEISMIC INTENSITIES

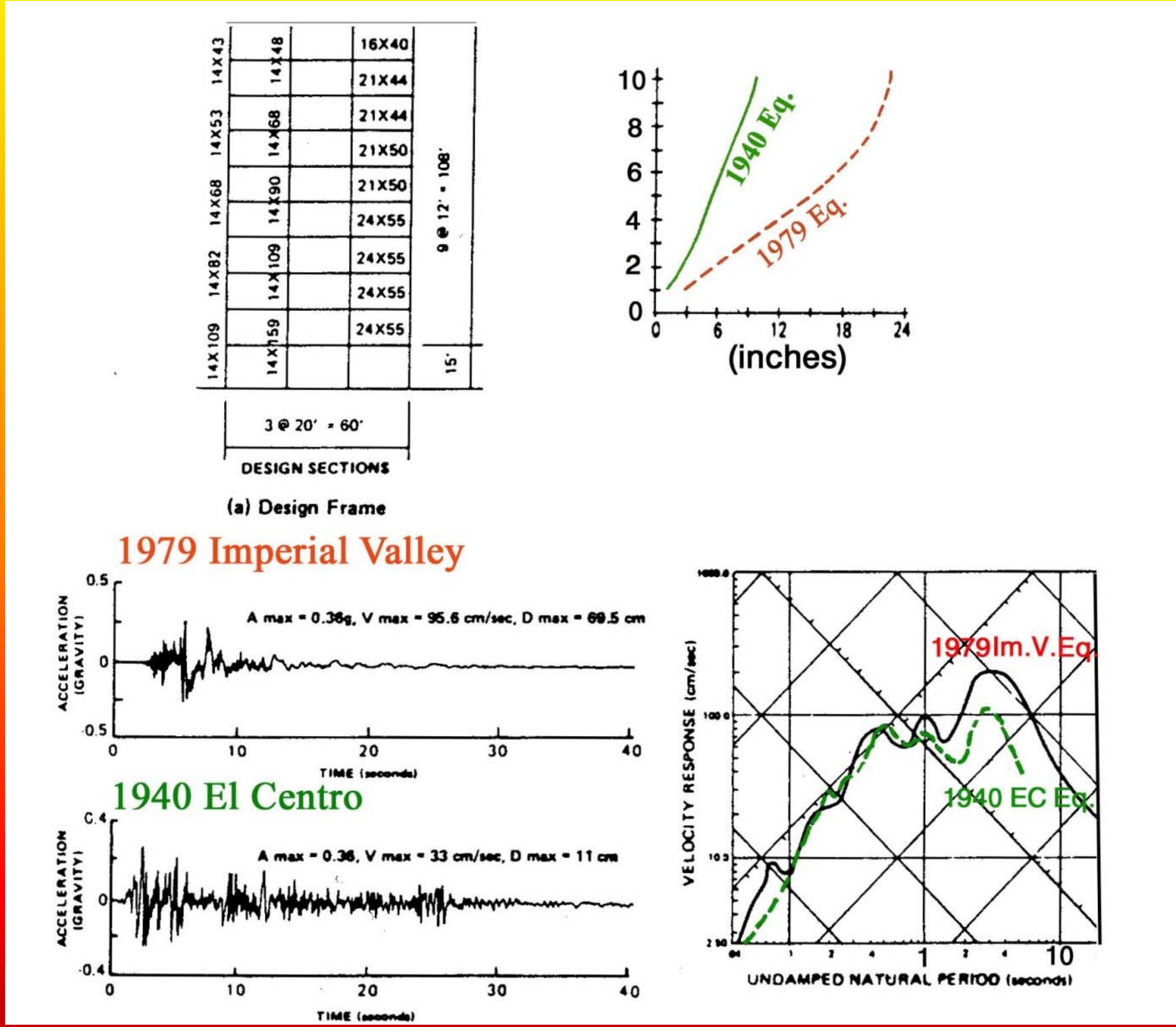
WHY ???

- Attenuation for Probabilistic Seismic Hazard
- **Macroseismic field**
- **Validation the results of Hazard analysis**
- **Hazard assessment in terms of statistical treatment of macroseismic intensities**.

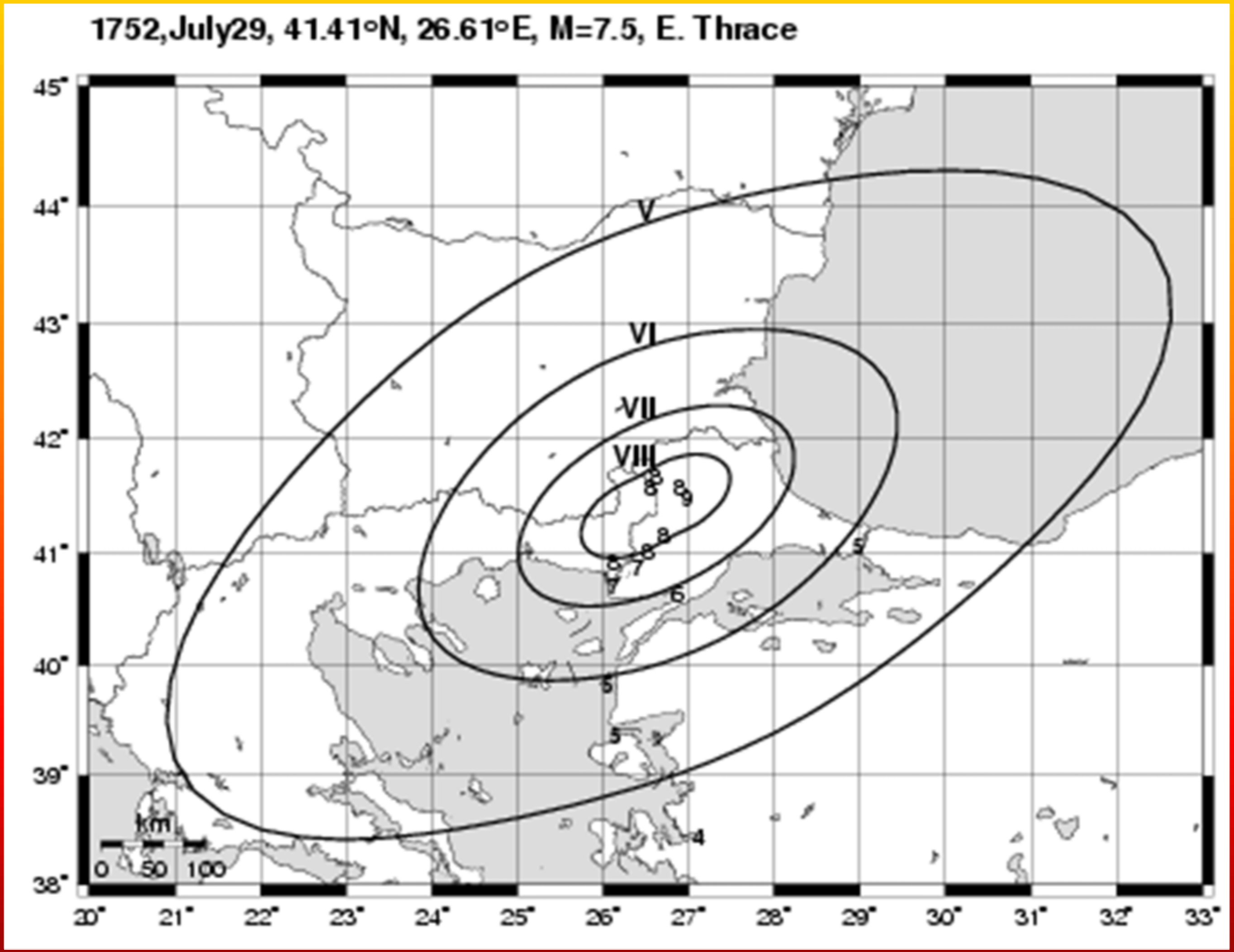
The macroseismic intensities

reflect the total result

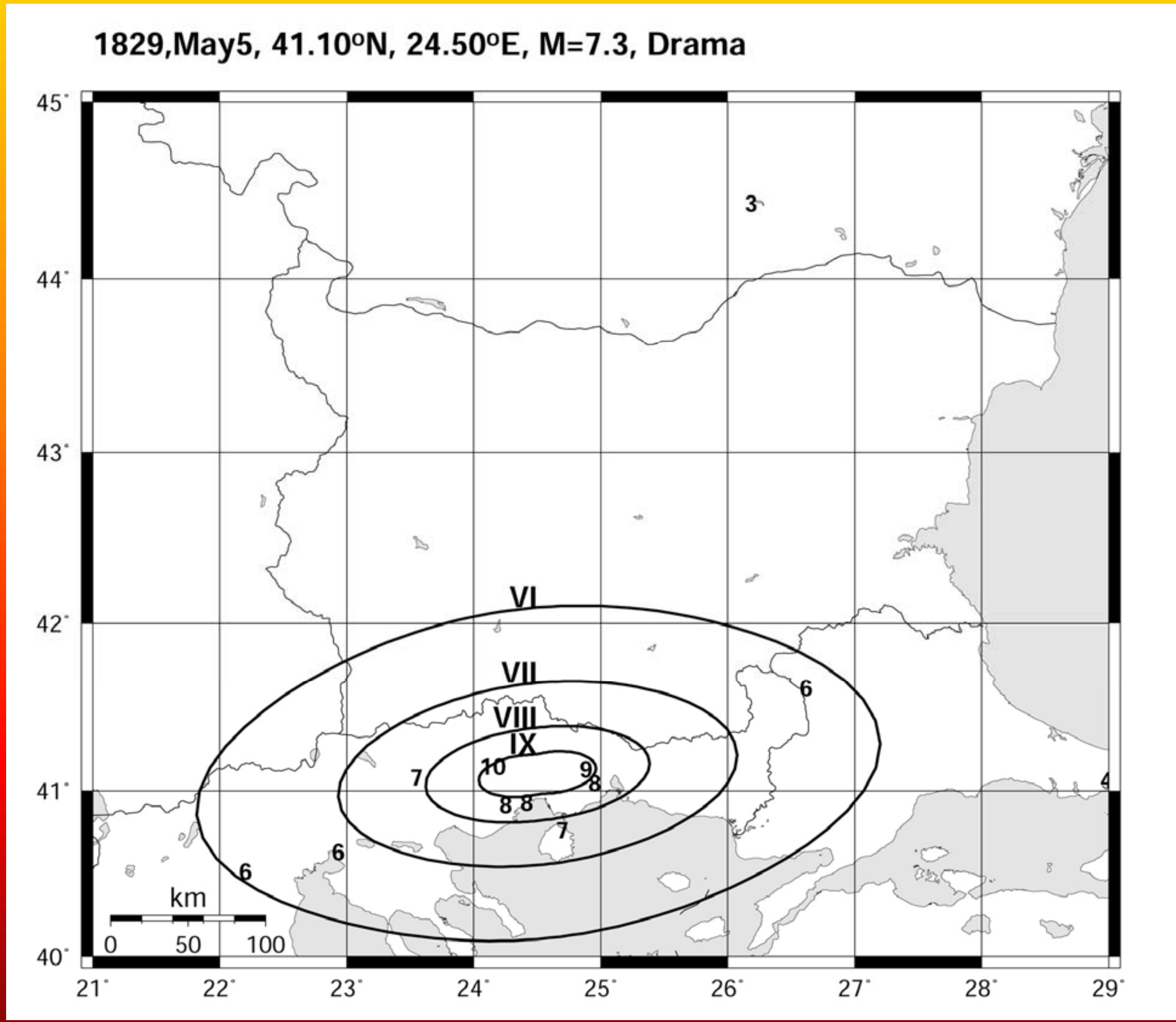
of the ground motion



Notice the **different response** of the structure due to different accelerograms with the **same (0.36g) PGA**.

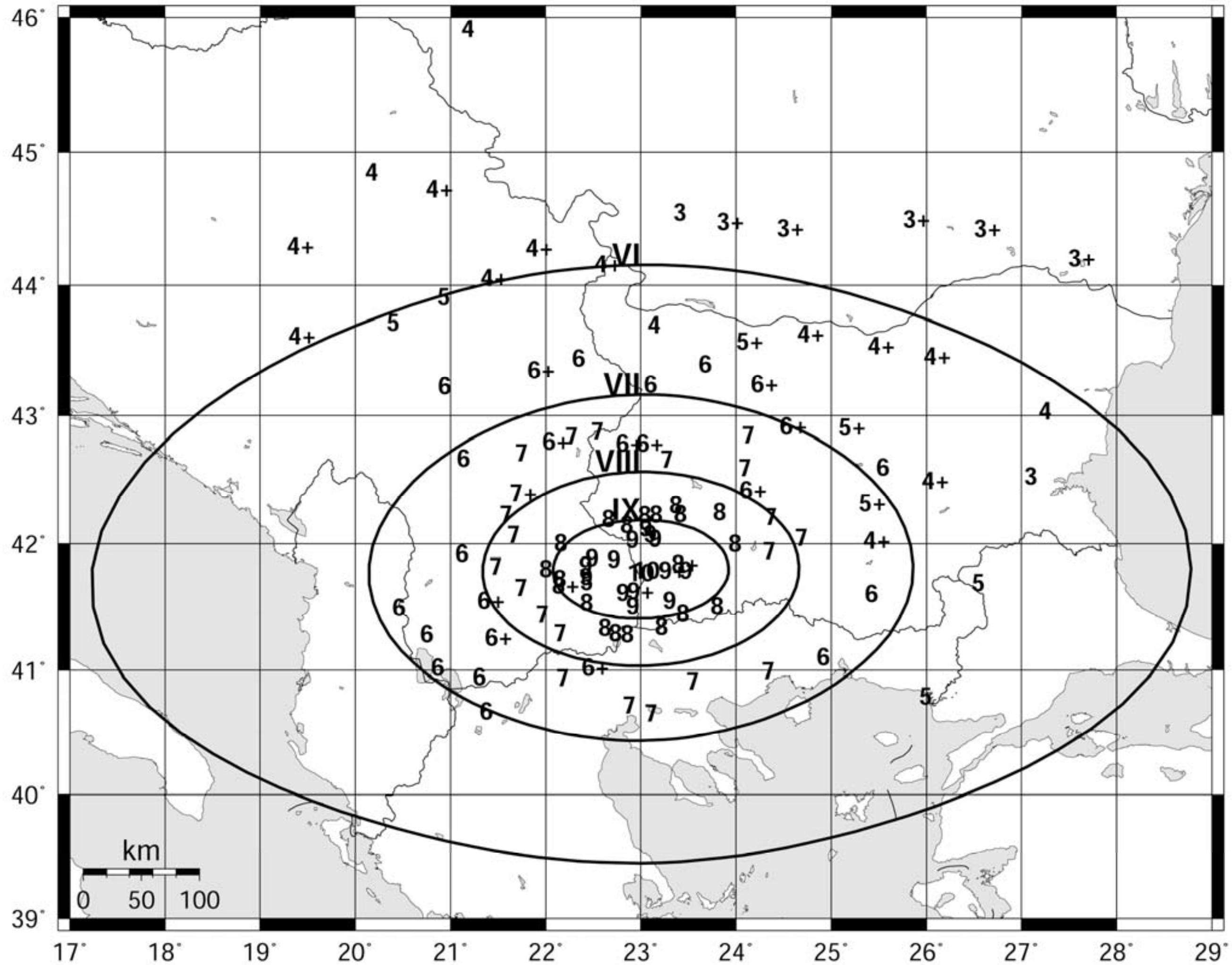


Papazachos et al., 1997.

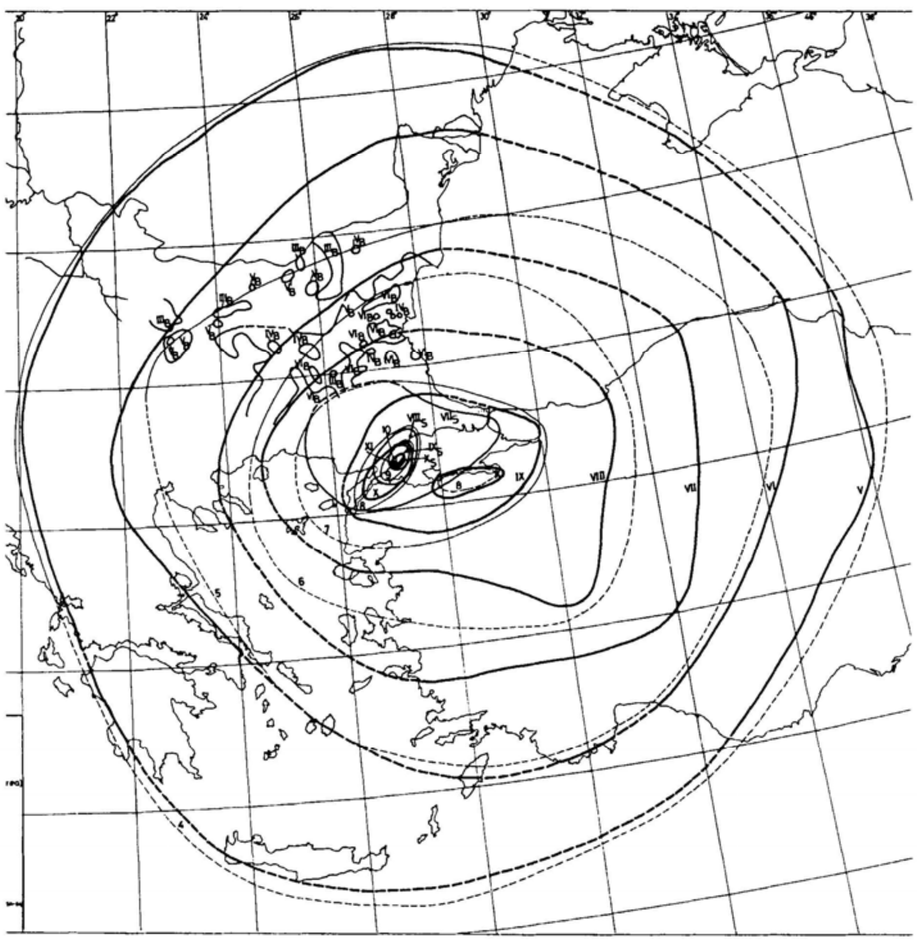


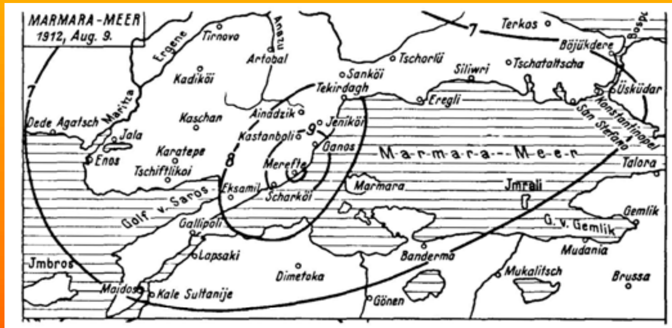
Papazachos et al., 1997.

1904,Apr.4, 41.80ºN, 23.00ºE, M=7.7, Bulgaria

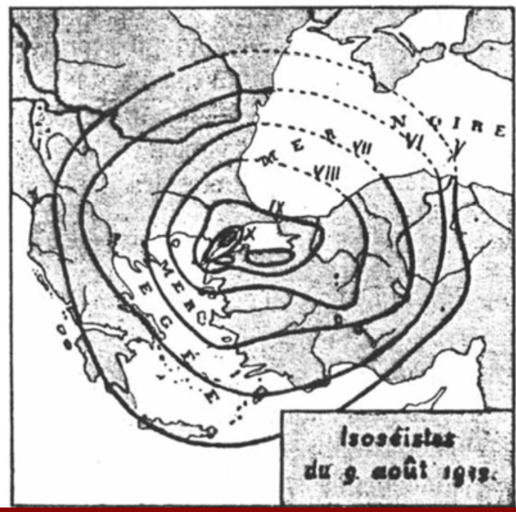


Papazachos et al., 1997.



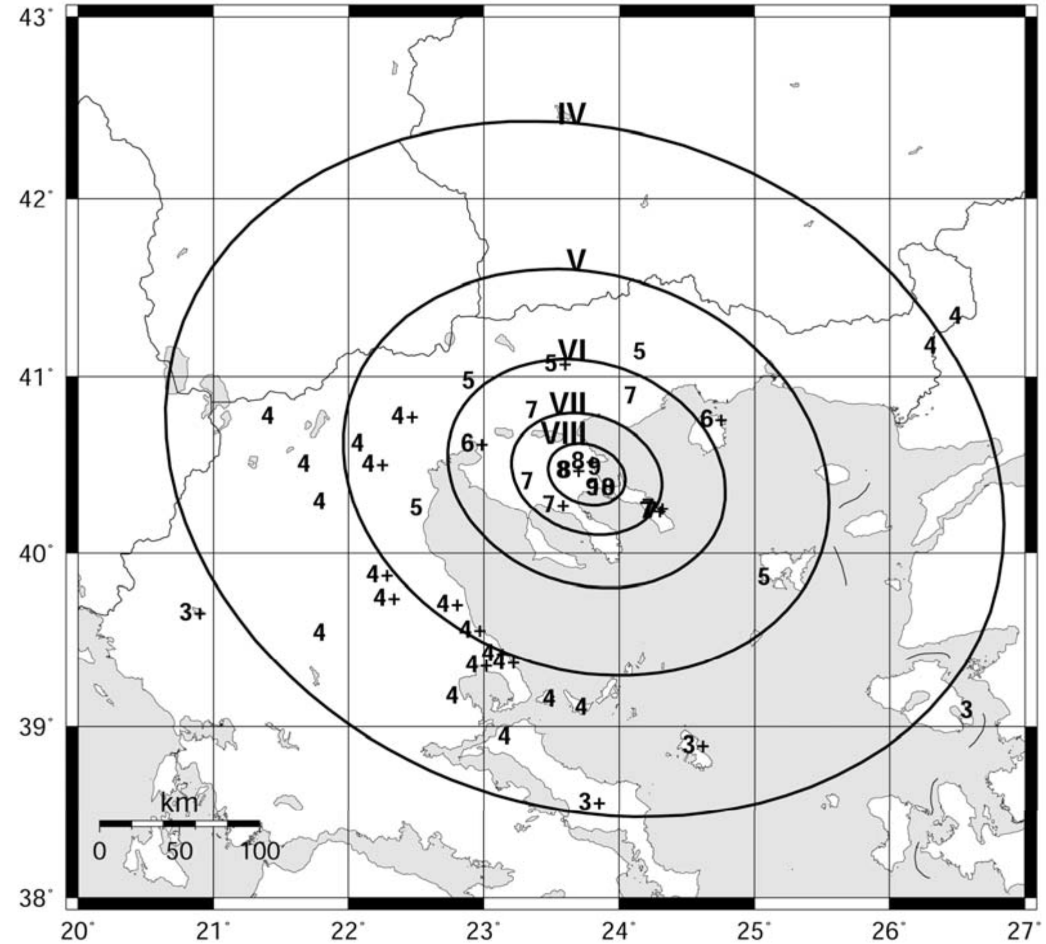


…eismal map of the earthquake of 9 August 1912 constructed by Sieberg[49] in terms of the Mercalli–Sieberg sc… following isoseismal radii may be assigned: $r_{10} = 9$, $r_9 = 15$, $r_8 = 33$, $r_7 = 105$ km



Shebalin et al.

1932,Sep.26, 40.45ºN, 23.76ºE, M=7.0, Hierissos



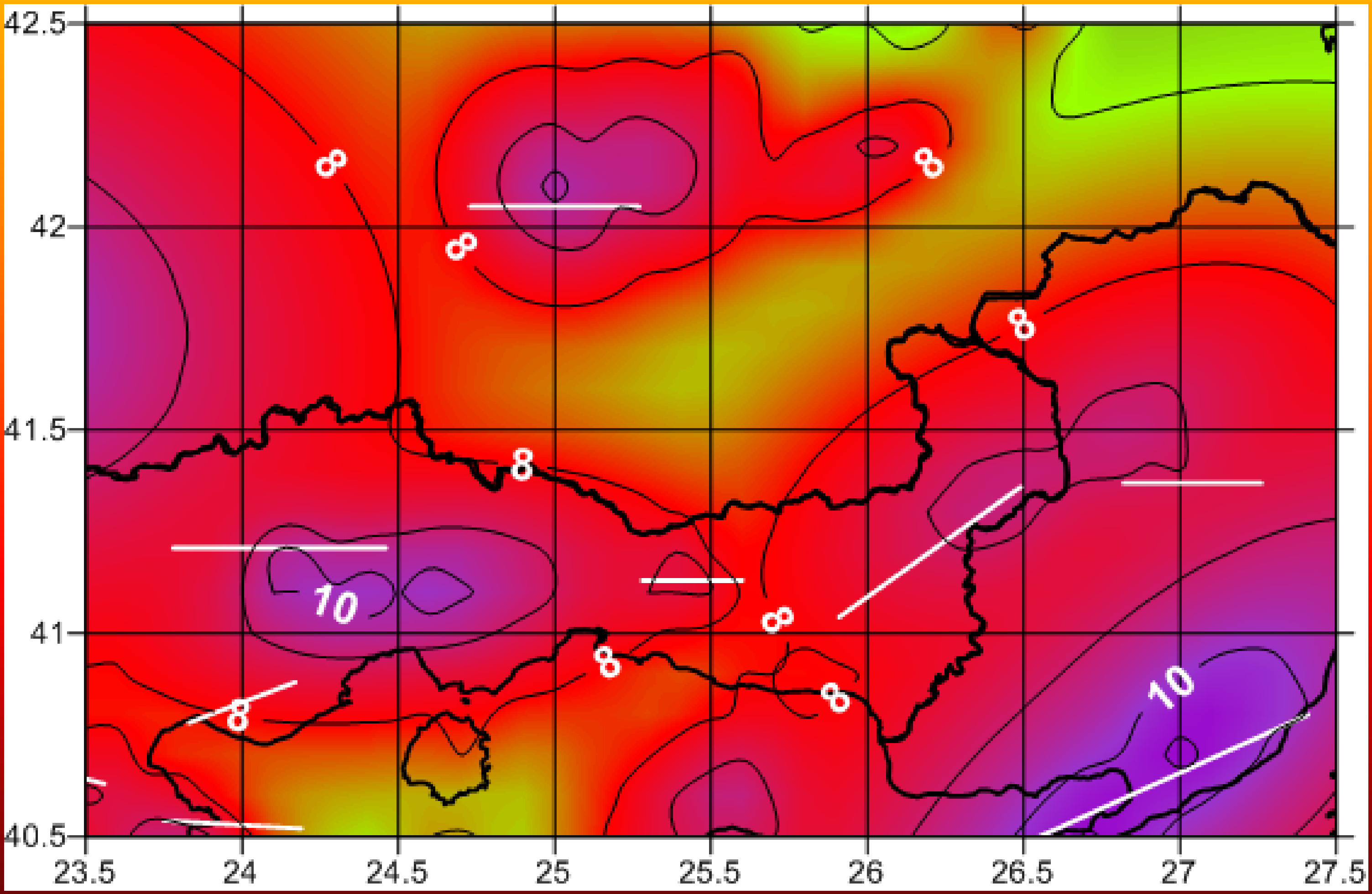
Papazachos et al., 1997.

Project funded by the EUROPEAN UNION

SciNet NatHaz Prevention

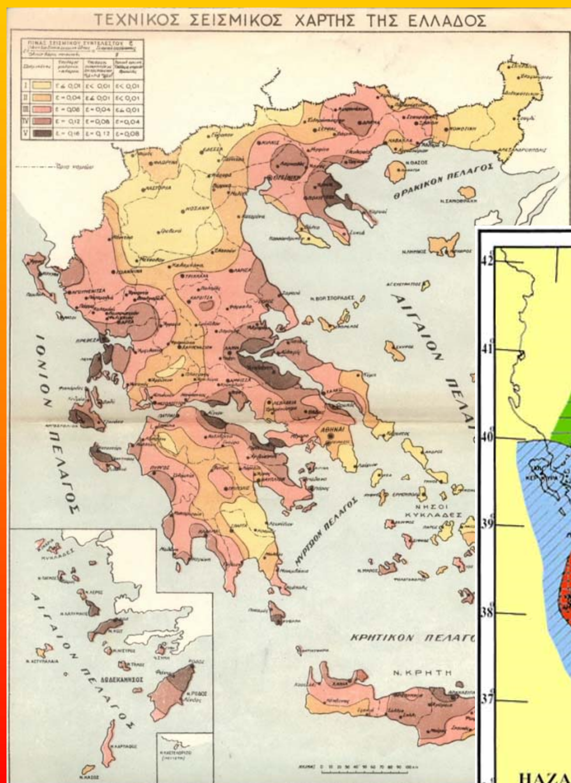
Black Sea CROSS BORDER COOPERATION

MAP OF MAXIMUM OBSERVED INTENSITIES



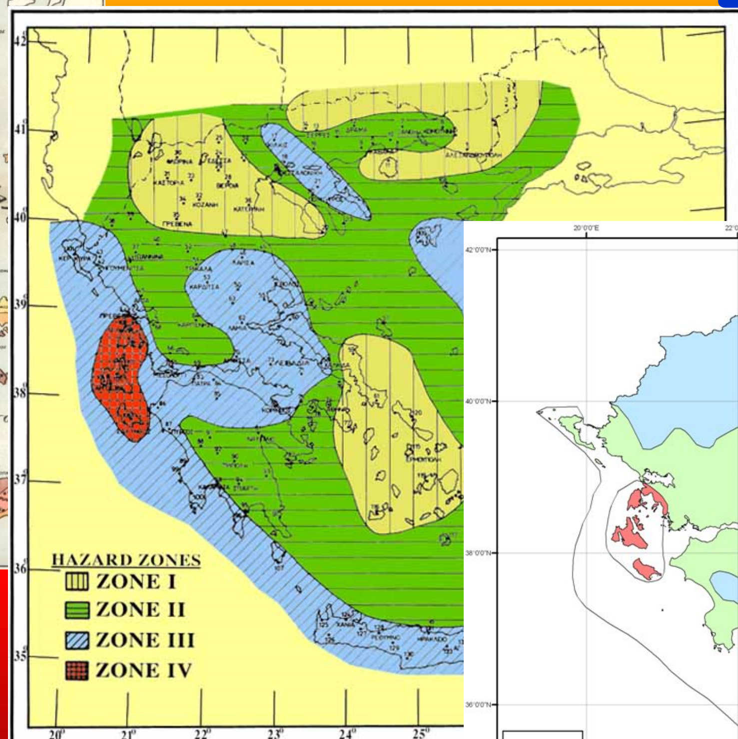
METHODOLOGIES APPLIED FOR SEISMIC HAZARD ASSESSMENT

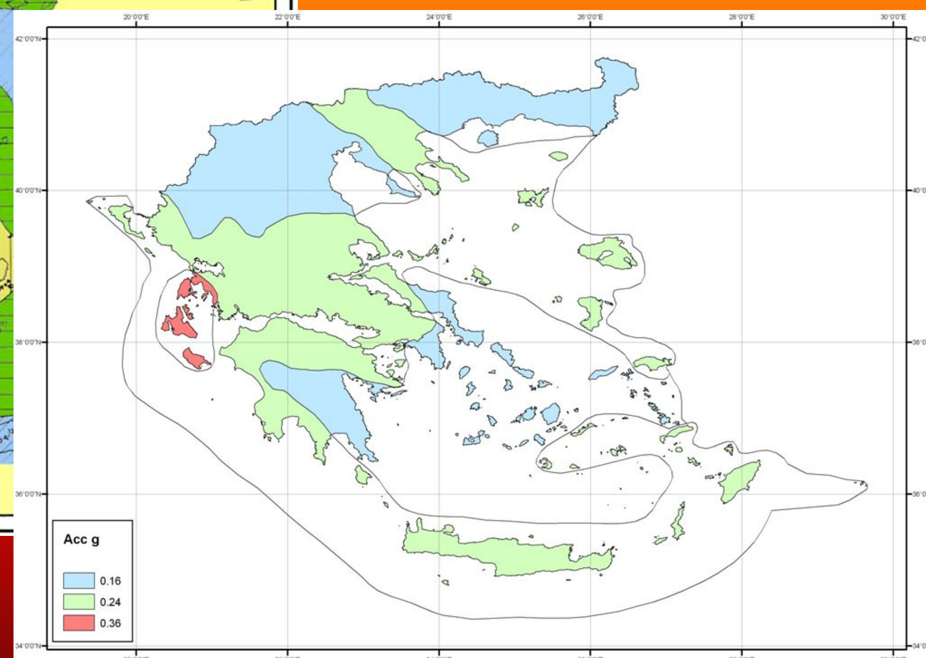
1. PROBABILISTIC METHODS BASED ON THE CORNELL'S (1968) AND ITS MODIFICATION BY MCGUIRE (1976) USING AREA- AND LINE- TYPE SOURCES
2. PROBABILISTIC METHOD BASED ON THE STATISTICAL TREATMENT OF OBSERVED INTENSITIES.



1956
Roussopoulos

1989
(Effective since 1995)
4 Seismological Centers

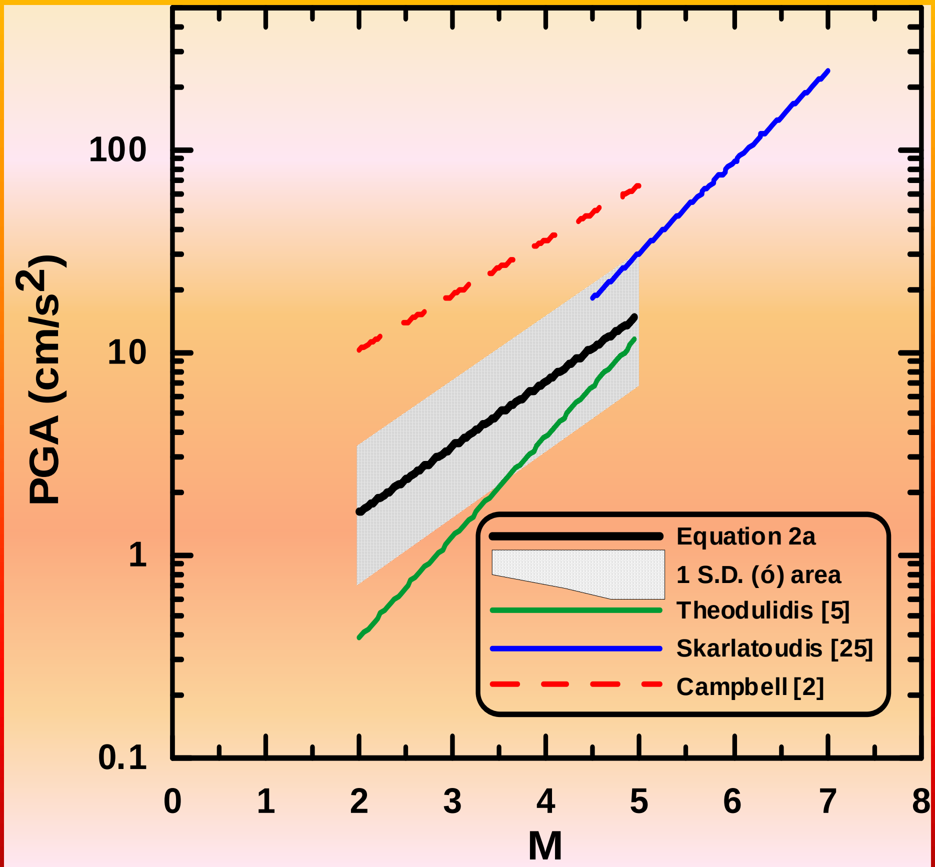


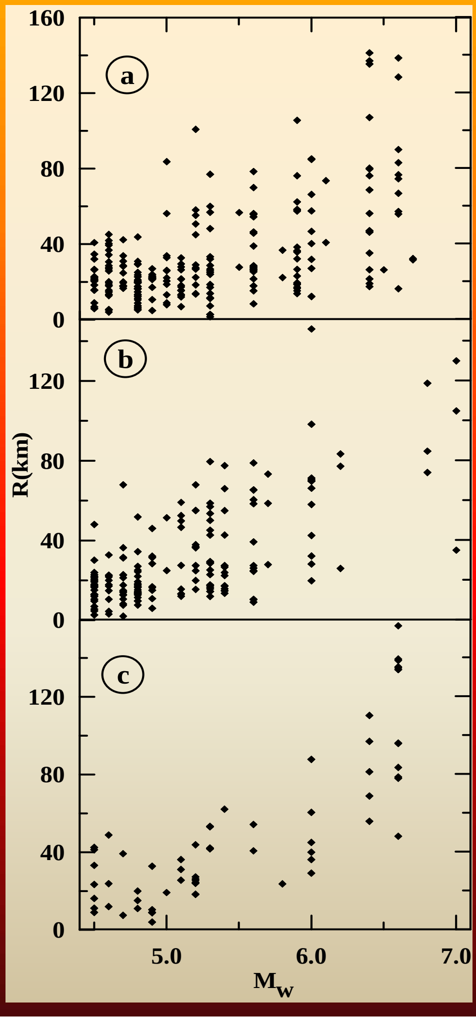


2001: All (5) the seismological institutions

EMPIRICAL PREDICTIVE RELATIONS FOR PGA
SMALL VS MODERATE-STRONG MAGNITUDES

SKARLATOUDIS ET AL. 2004, 2005

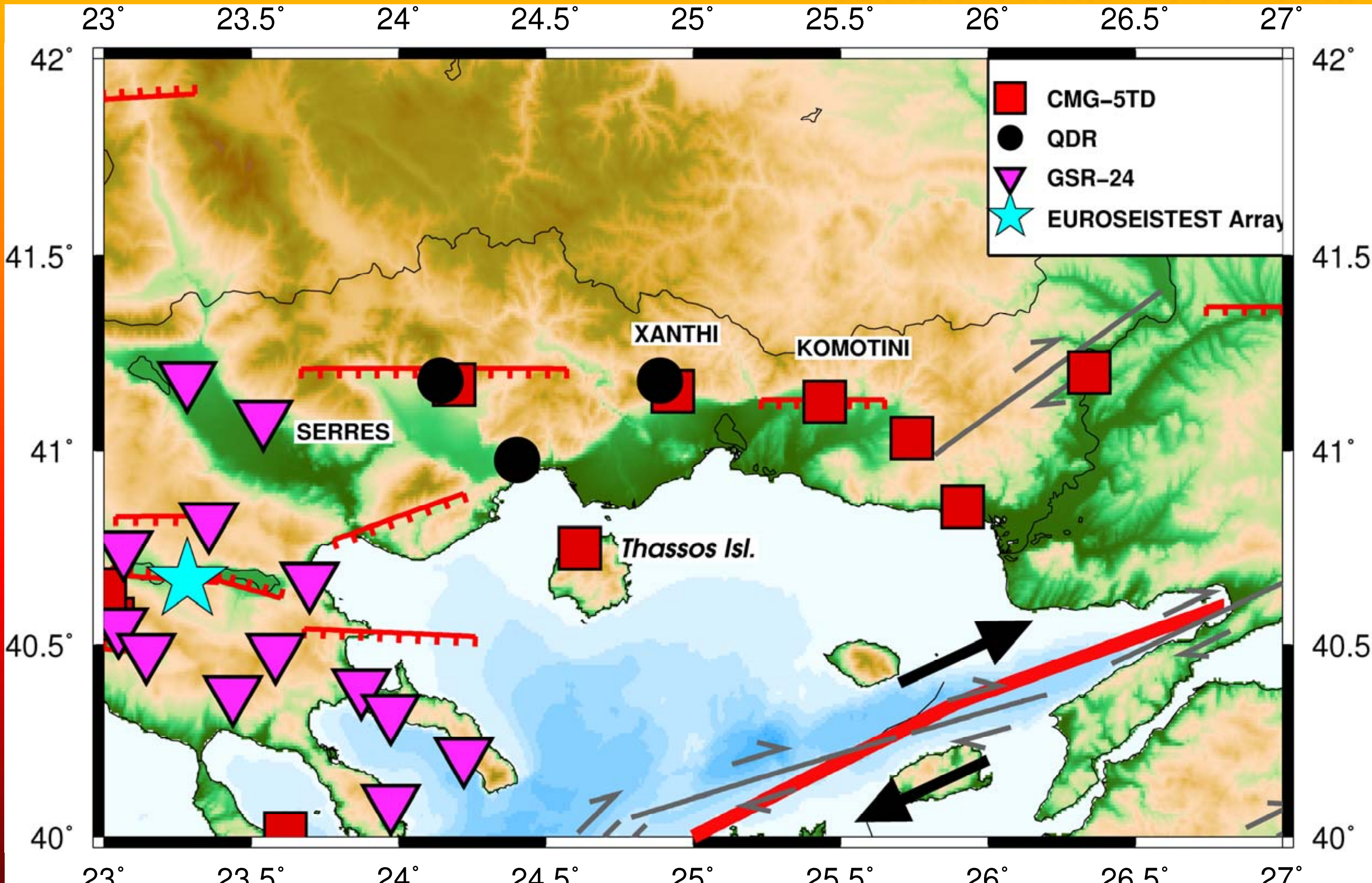


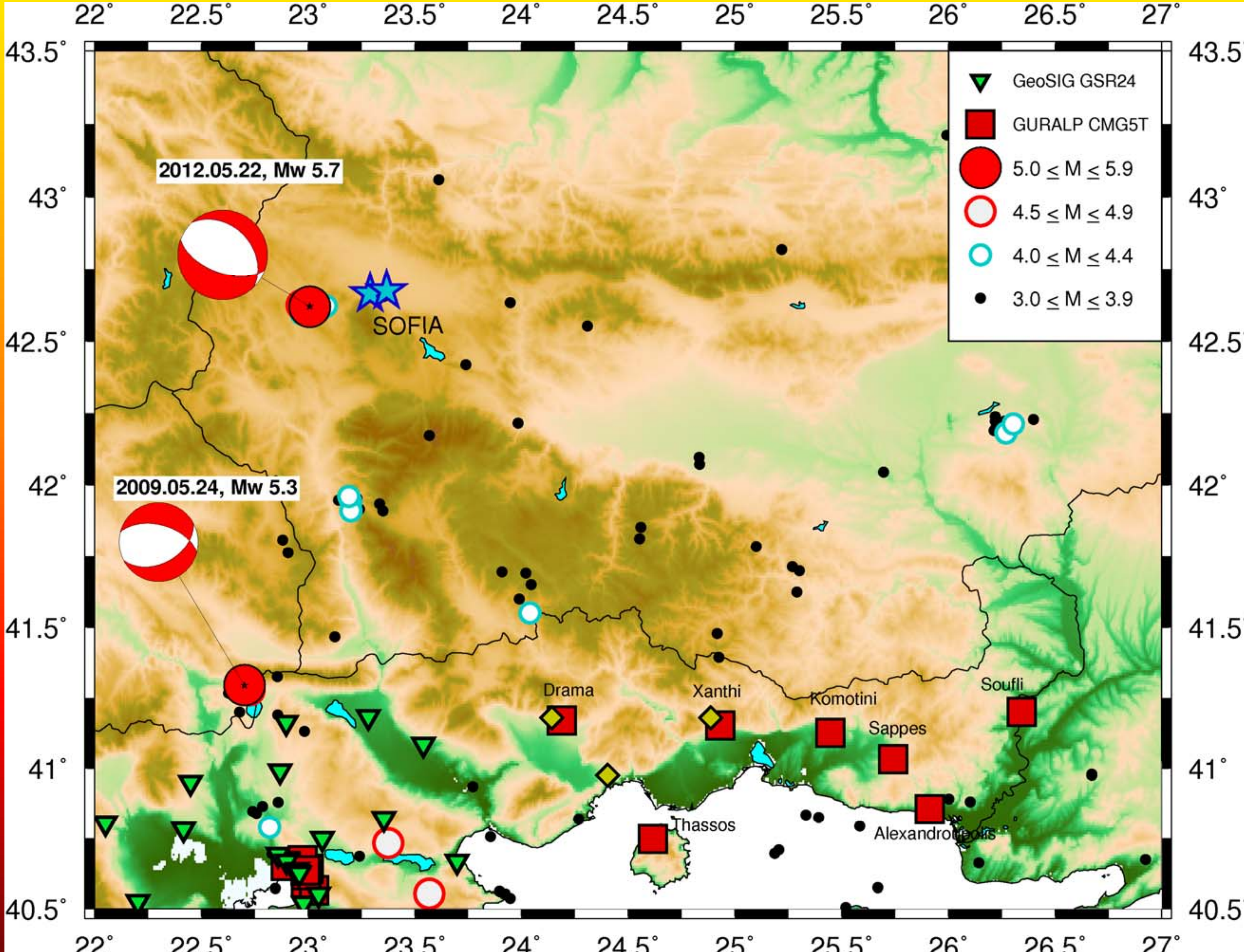


Notice the difference for smaller predicted PGA values (black line) compared to the corresponding ones from large magnitude earthquakes (blue line).

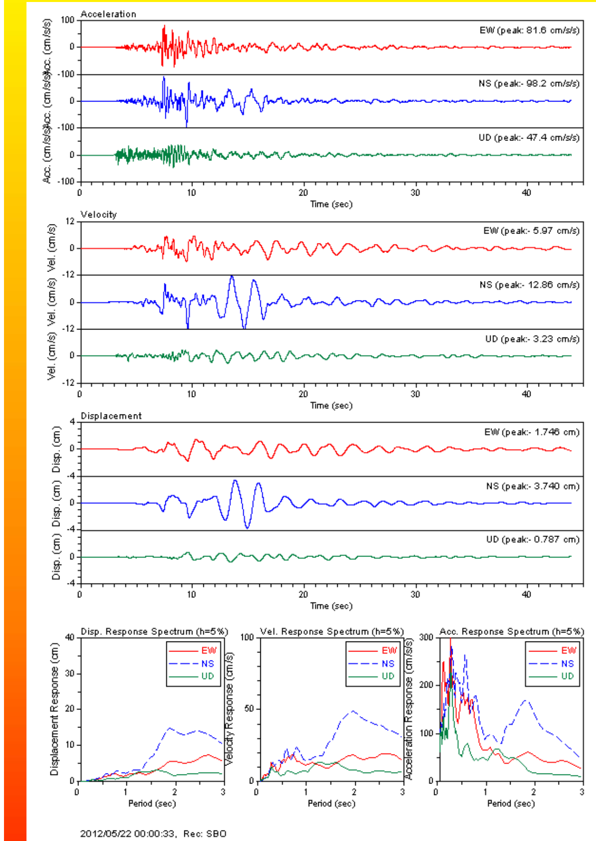
EMPIRICAL PREDICTIVE RELATIONS FOR PGA SMALL VS MODERATE-STRONG MAGNITUDES

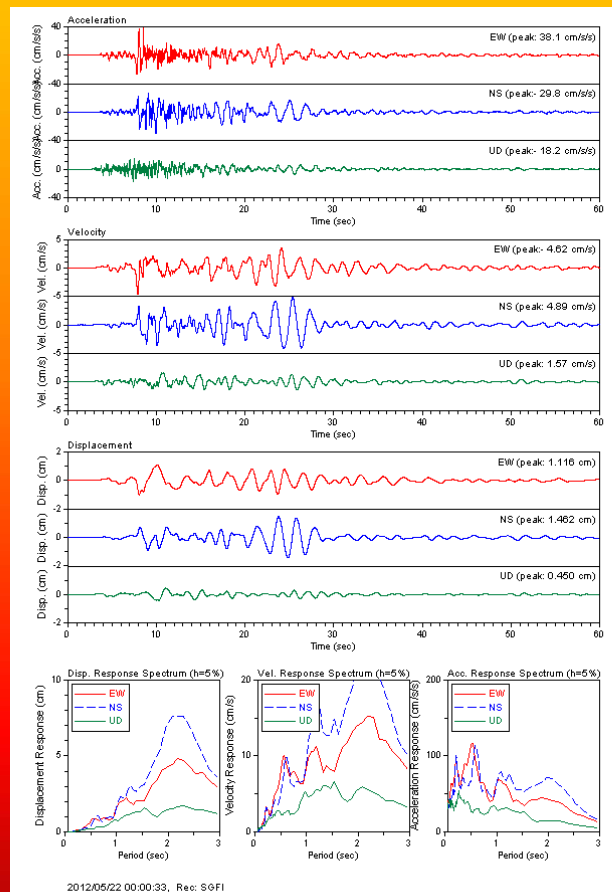
SKARLATOUDIS ET AL. 2004, 2005



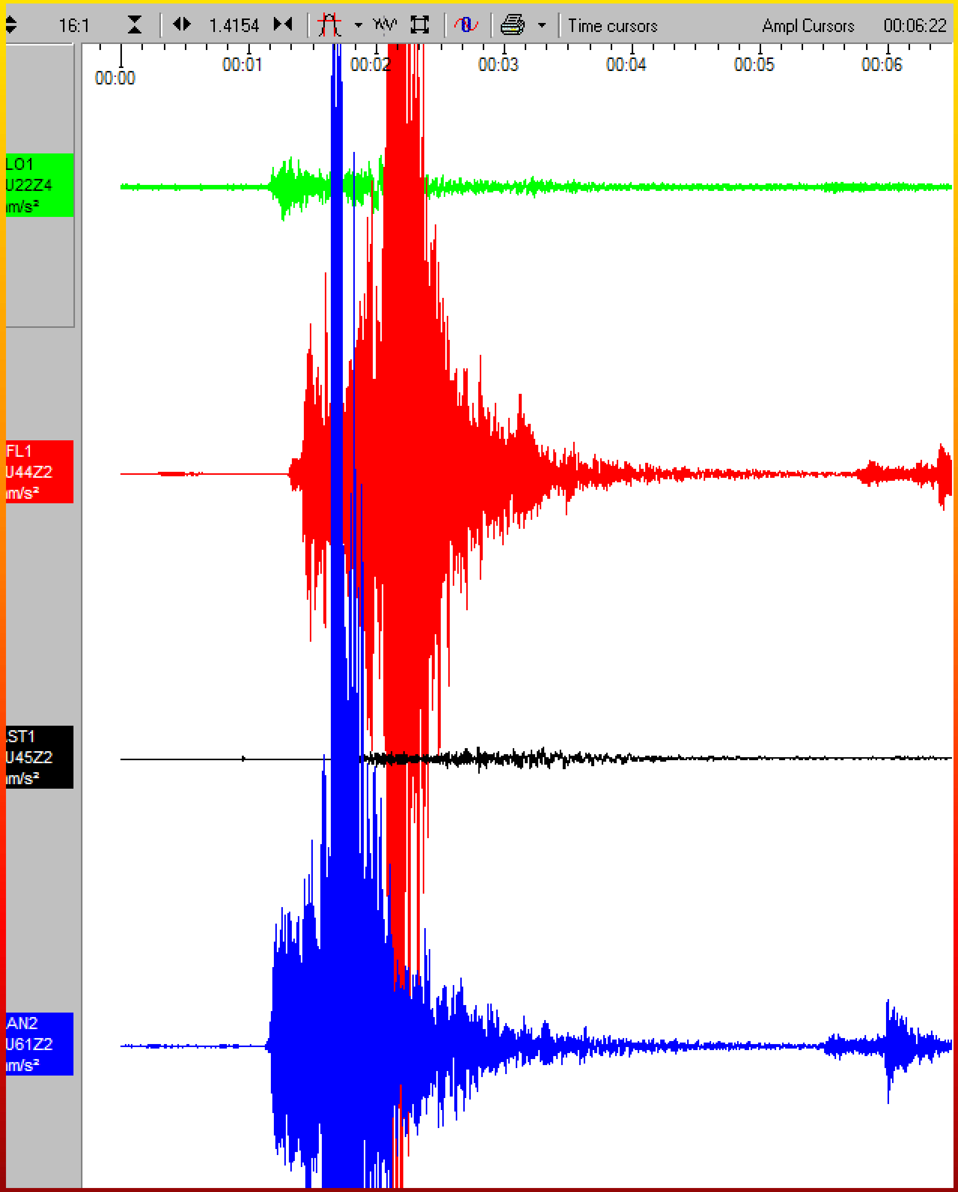


GeoSIG GSR24
GURALP CMG5T
5.0 ≤ M ≤ 5.9
4.5 ≤ M ≤ 4.9
4.0 ≤ M ≤ 4.4
3.0 ≤ M ≤ 3.9
2012.05.22, Mw 5.7
2009.05.24, Mw 5.3
SOFIA
Drama
Xanthi
Komotini
Soufli
Sappes
Thassos
Alexandroupolis
22° 22.5° 23° 23.5° 24° 24.5° 25° 25.5° 26° 26.5° 27°
43.5° 43° 42.5° 42° 41.5° 41° 40.5°



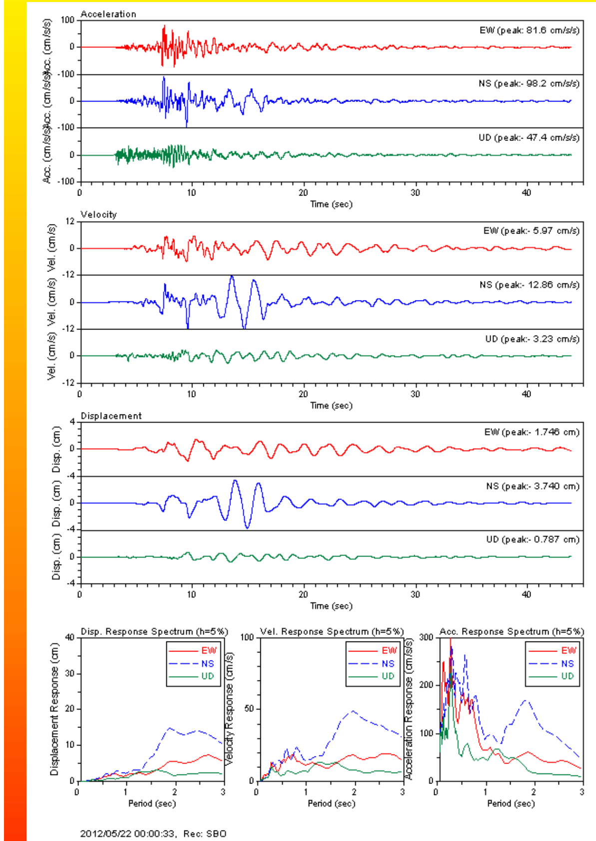


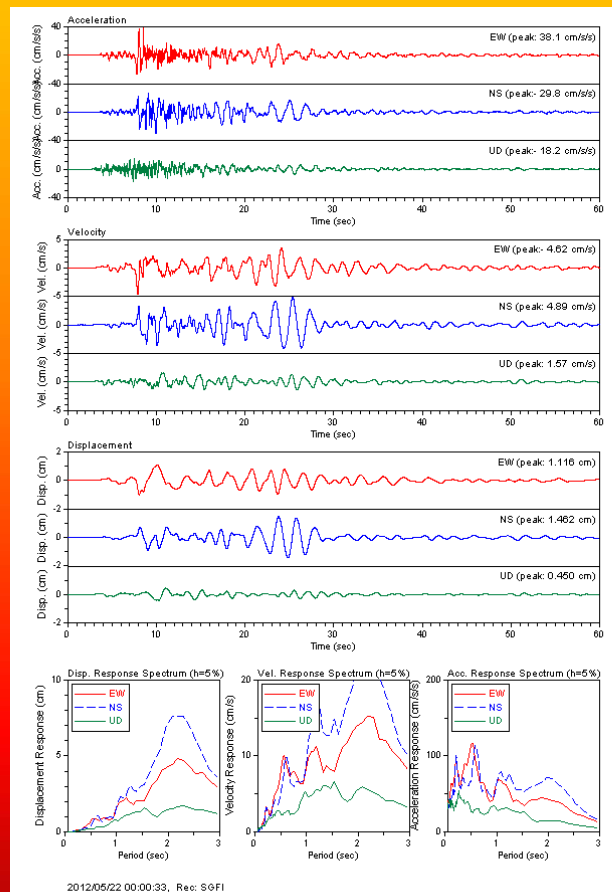
HORIZONTAL COMPONENTS			
Component	Distance	PGA	PGV/PGA
KMT_N	260	8.2	0.12
KMT_E	260	7.88	0.12
THS_E	246	3.25	0.07
THS_N	246	5.99	0.06
SAP_E	285	4.27	0.16
SAP_N	285	5.09	0.13
SFL_N	316	12.62	0.07
SFL_E	316	10.97	0.08
XAN_N	226	6.47	0.14
XAN_E	226	10.56	0.09
SBO_E	32	91.6	0.065175
SBO_N	32	98.2	0.130957
SGF_E	41	38.1	0.12126
SGF_N	41	29.88	0.163655



Records at distant Greek stations

Notice the high quality of the records





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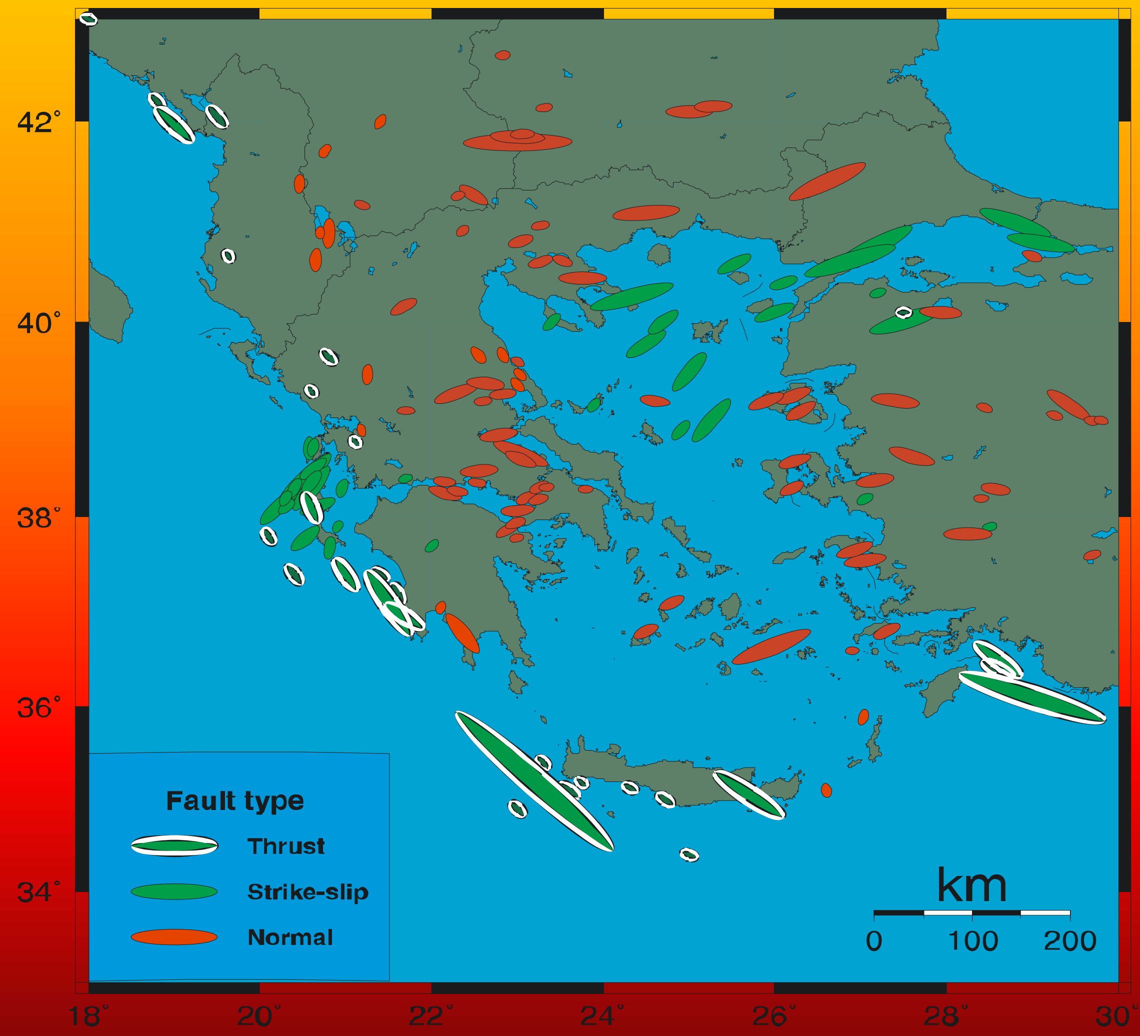
SGF_E	41	38.1	0.12126
SGF_N	41	29.88	0.163655

RUPTURE ZONES OF KNOWN EQS.
550 B.C. - 1997



Papazachos et al., 1999

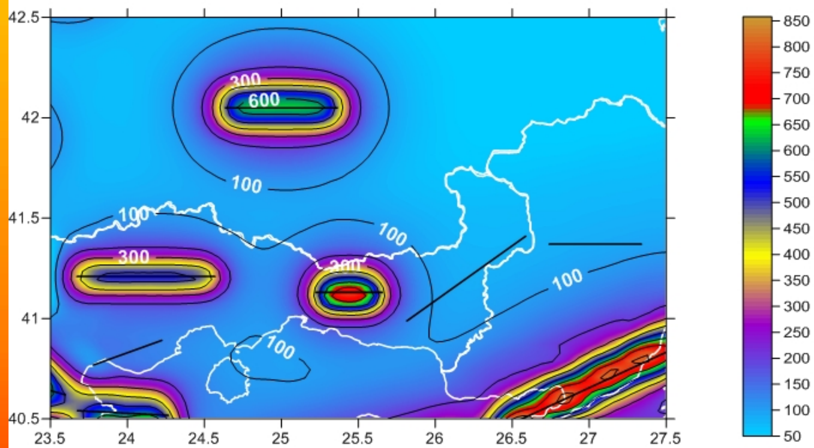
METHODOLOGIES APPLIED FOR SEISMIC HAZARD ASSESSMENT

MCGUIRE (1976) & FRISK88M

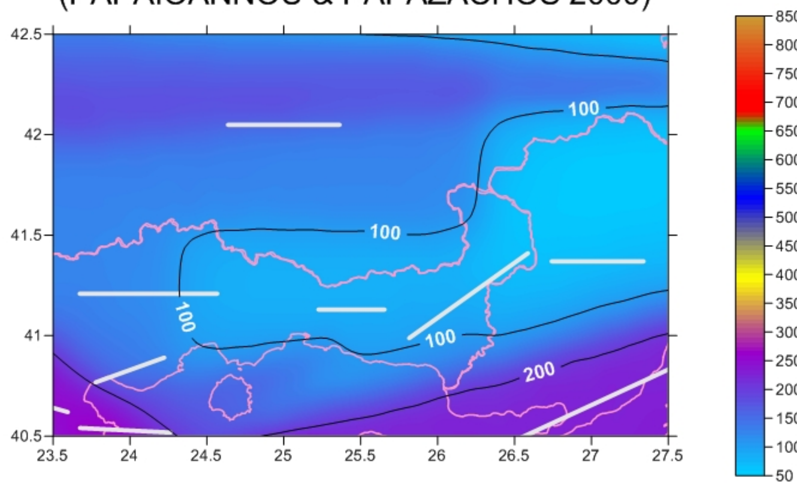
BOTH WERE MODIFIED FOR THE ATTENUATION OF SMALL MAGNITUDE EARTHQUAKES AND CONSIDERATION OF VARIOUS PREDICTIVE RELATIONS HOLDING FOR DIFFERENT TECTONIC ENVIRONMENTS.

Project funded by the EUROPEAN UNION

HYBRID MODEL OF AREA AND FAULT -TYPE SOURCES

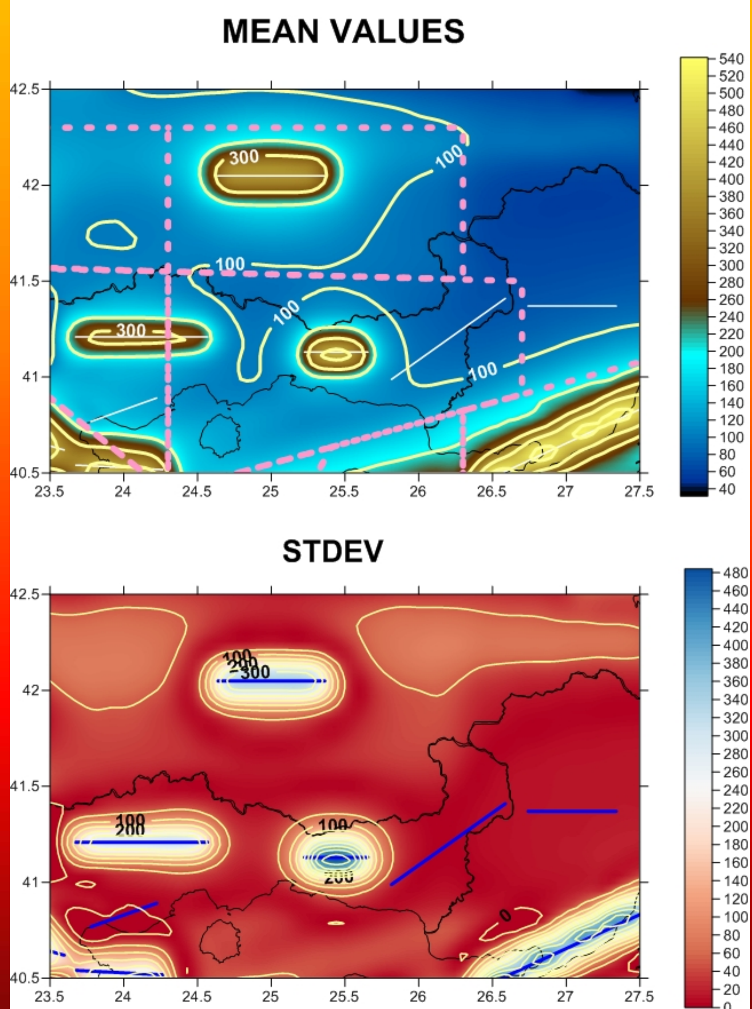


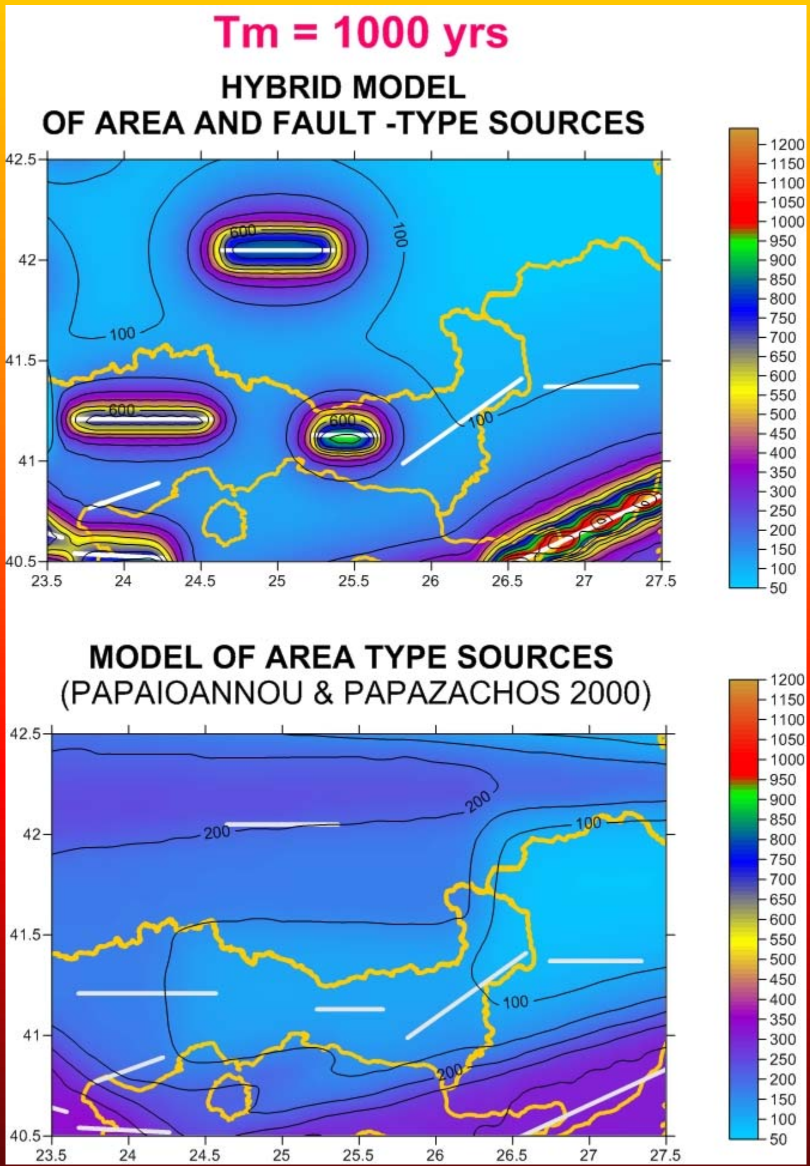
MODEL OF AREA TYPE SOURCES (PAPAIOANNOU & PAPAZACHOS 2000)



RESULTS FOR T_M =476 yrs

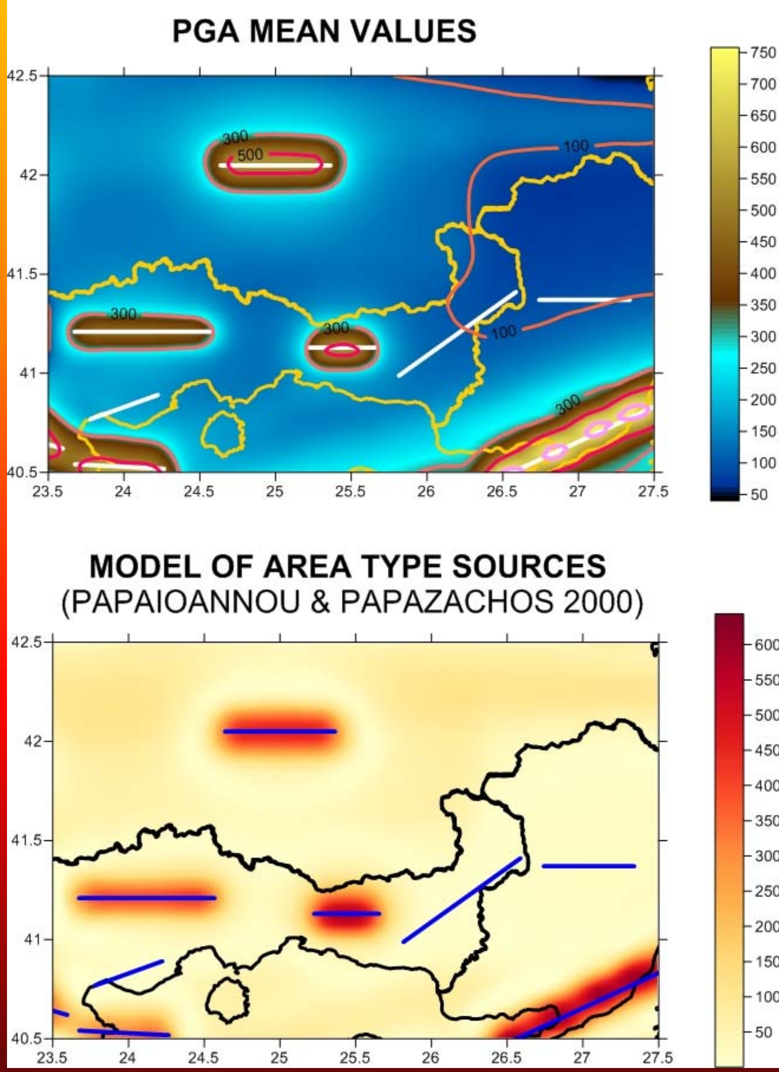
TM = 476 years


MEAN VALUES
STDEV
300
100
300
100
100
23.5
24
24.5
25
25.5
26
26.5
27
27.5
40.5
41
41.5
42
42.5
540
520
500
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0

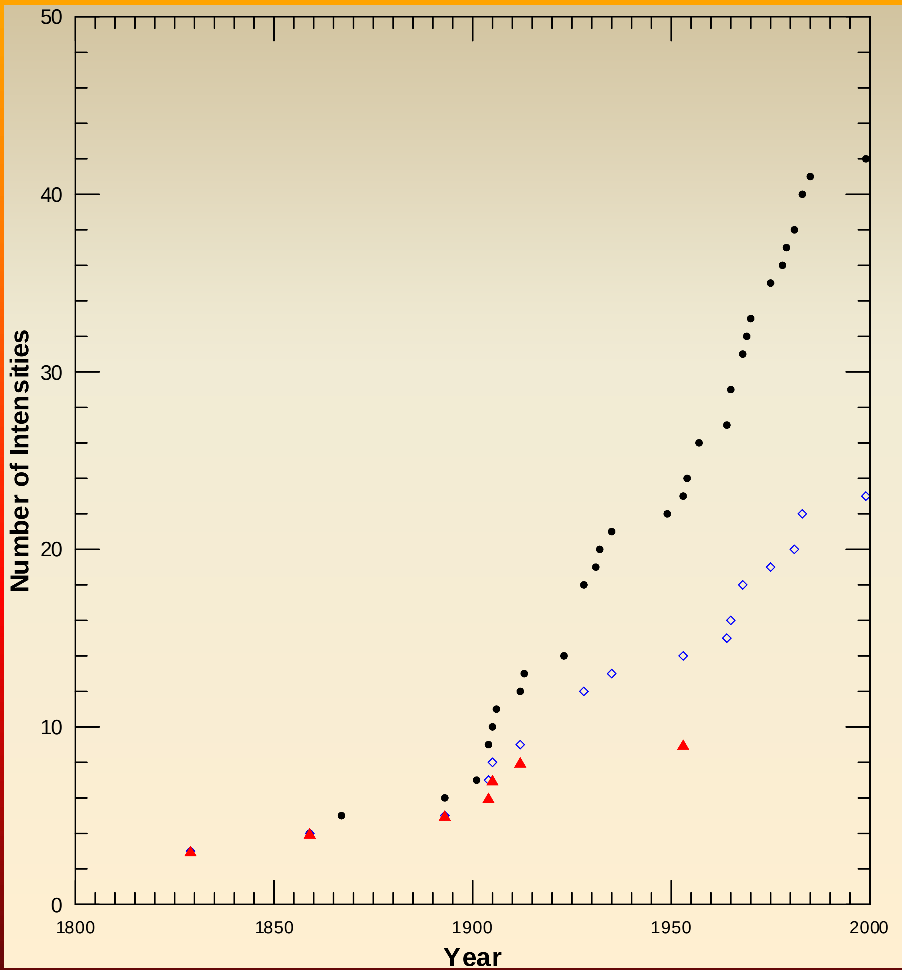


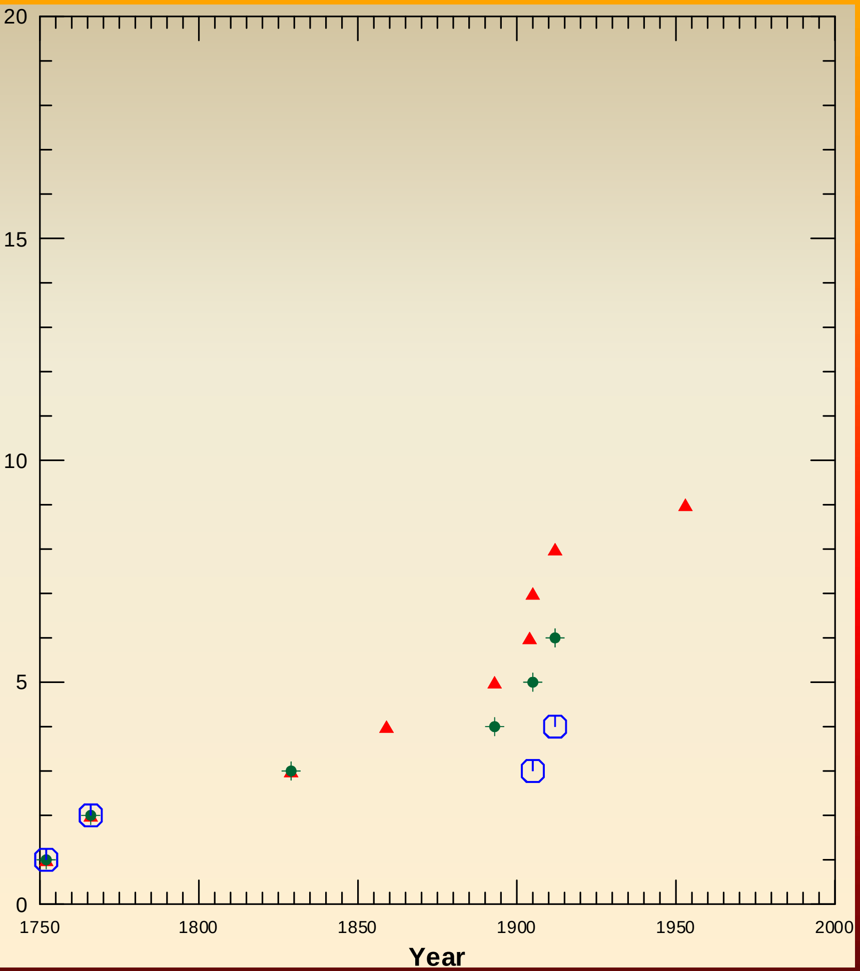
RESULTS FOR T_M = 952 yrs

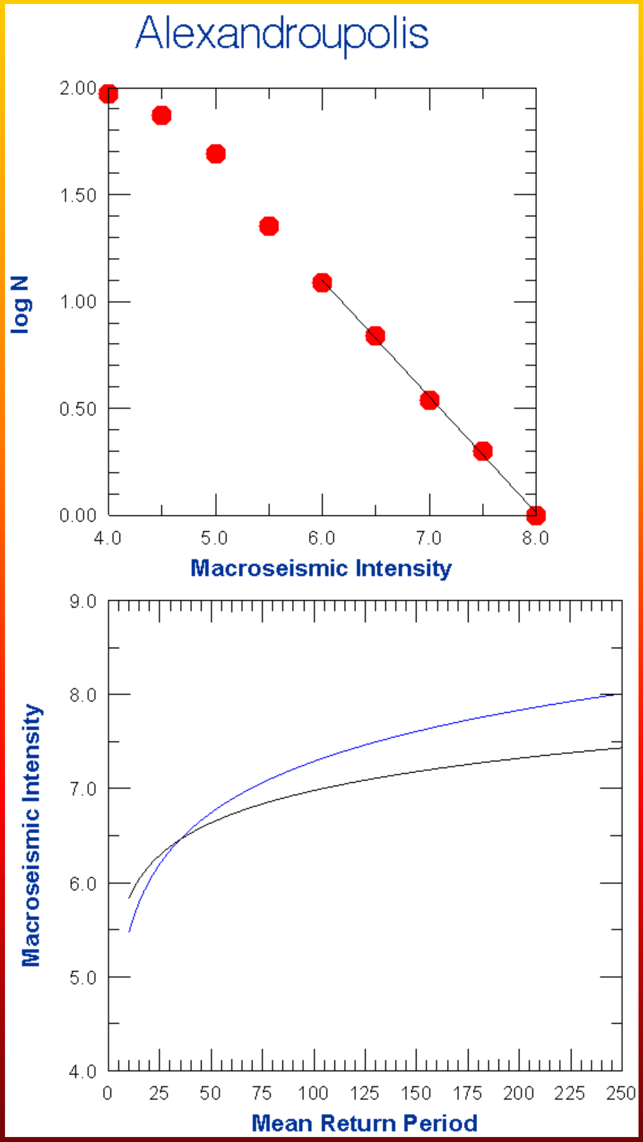
Tm = 1000 yrs


PGA MEAN VALUES
MODEL OF AREA TYPE SOURCES
(PAPAIOANNOU & PAPAZACHOS 2000)
42.5
42
41.5
41
40.5
23.5
24
24.5
25
25.5
26
26.5
27
27.5
300
500
100
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50

ALEXANDROUPOLIS INTENSITY RATE



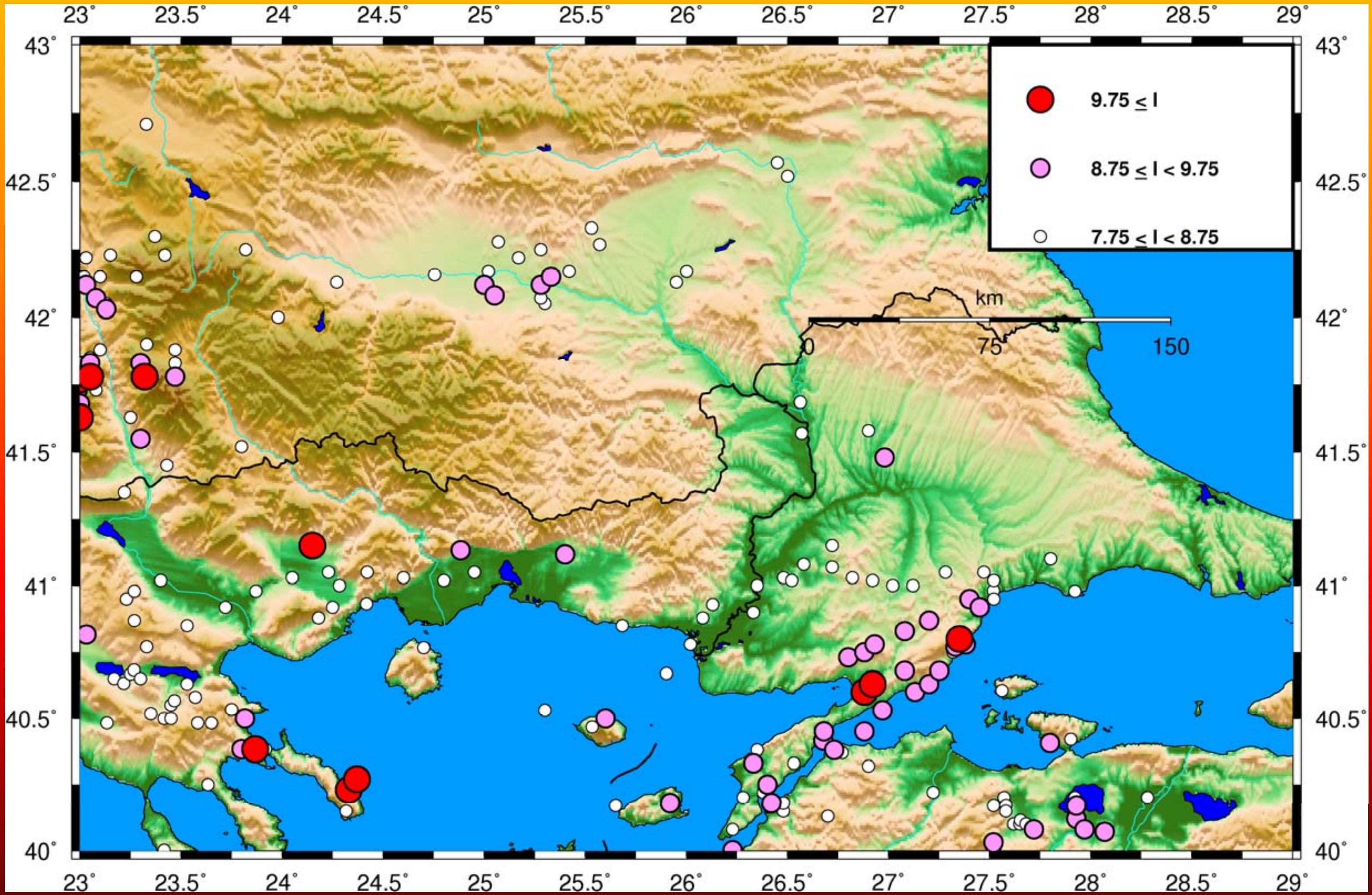




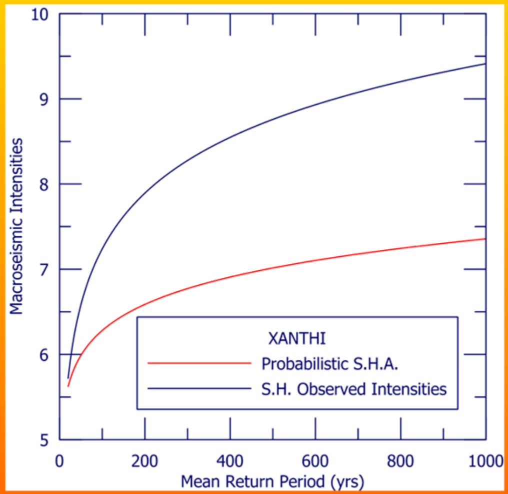
INTENSITY DISTRIBUTION

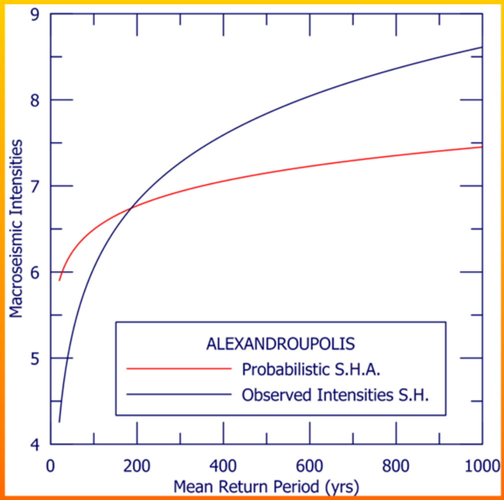
COMPARISON OF THE RESULTS

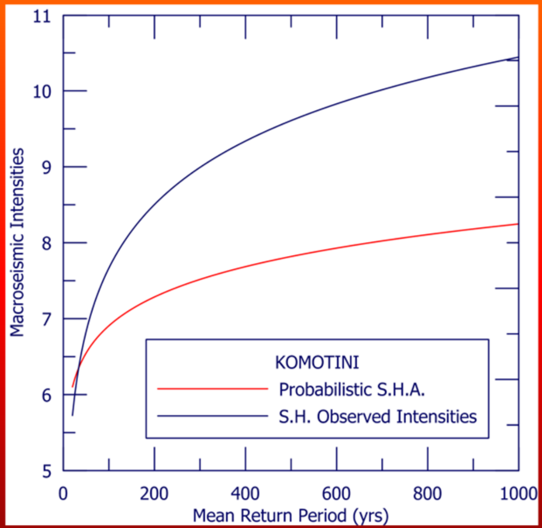
OBSERVED INTENSITIES DISTRIBUTION

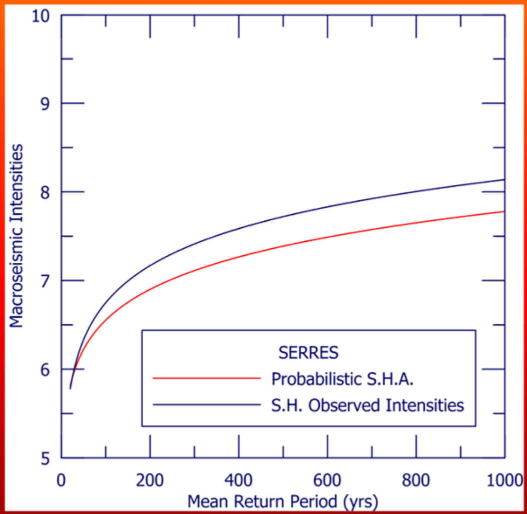


INTENSITY DISTRIBUTION









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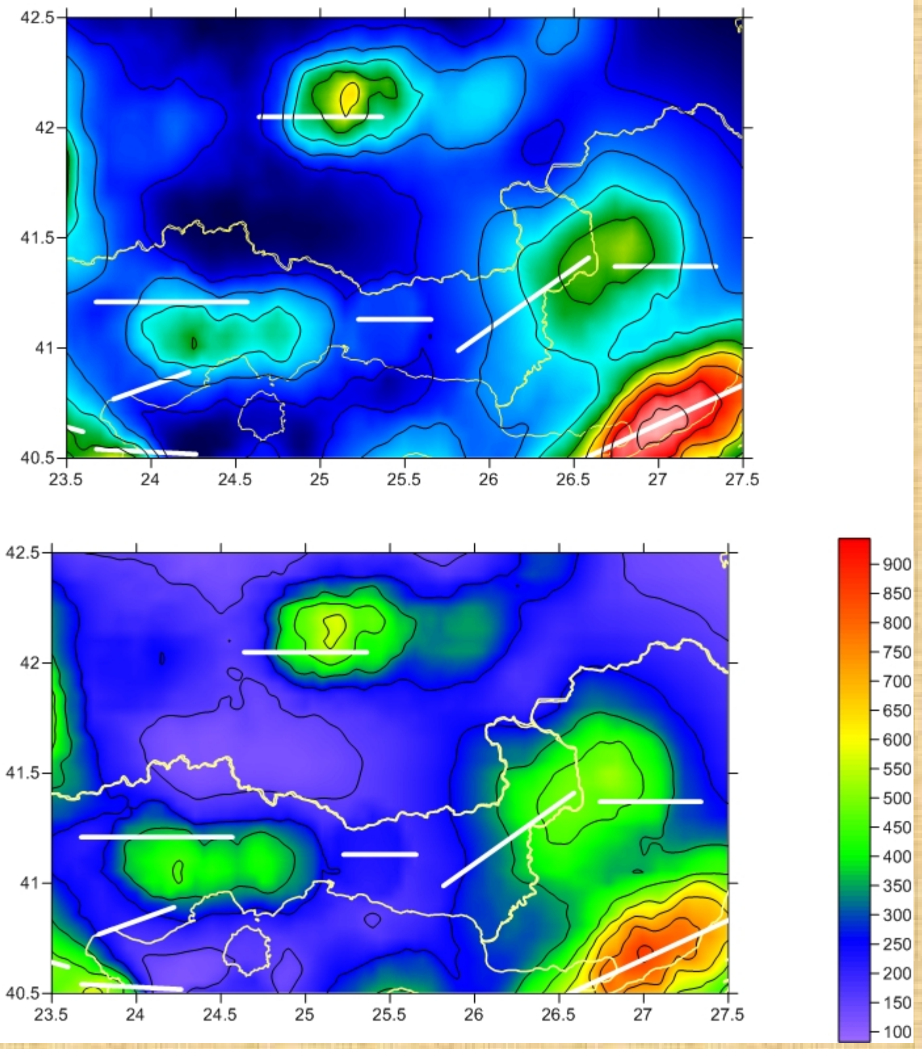
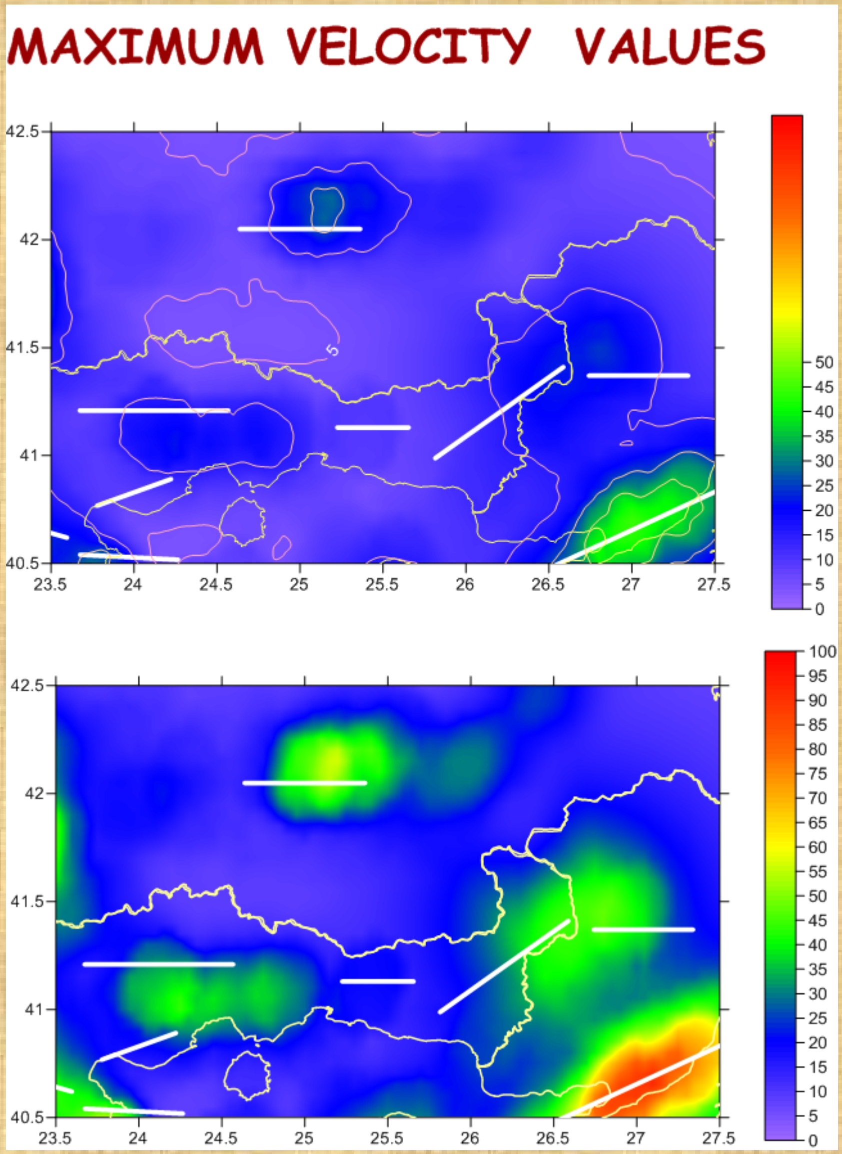
MAXIMUM ACCELERATION VALUES



Maps depicting the maximum PGA values for ROCK sites on the basis of the geographical distribution of maximum intensities converted to PGA & PGA+1σ using scaling relations.



Maps depicting the maximum PGV values for ROCK sites on the basis of the geographical distribution of maximum intensities converted to PGV & PGV+1σ using scaling relations.

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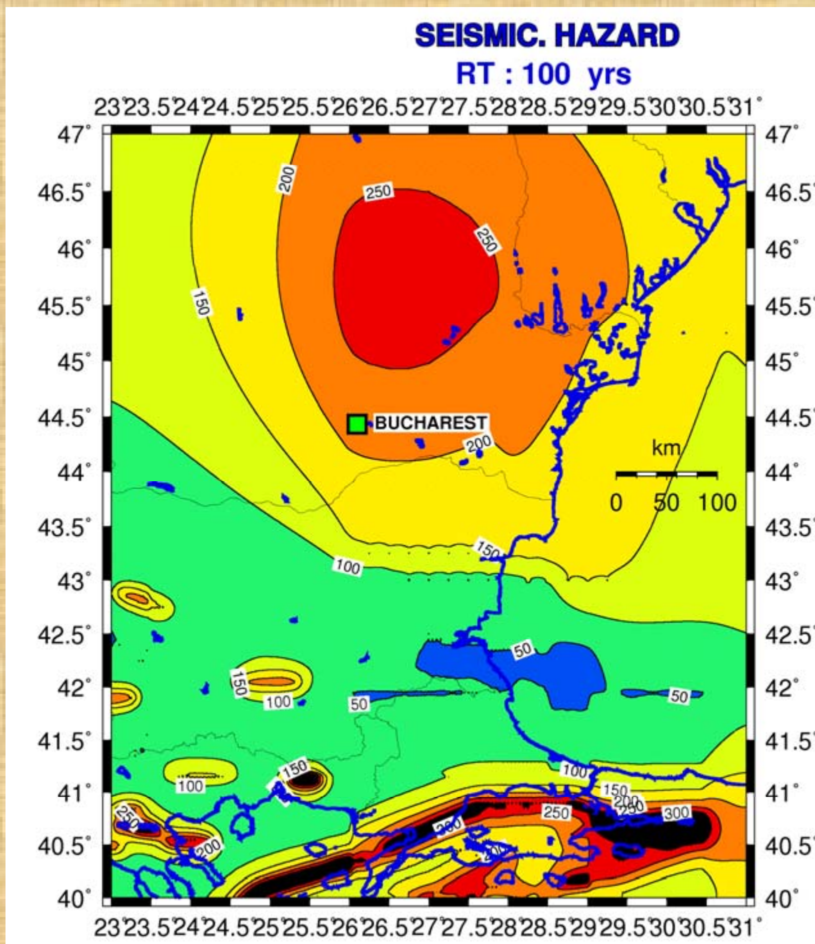

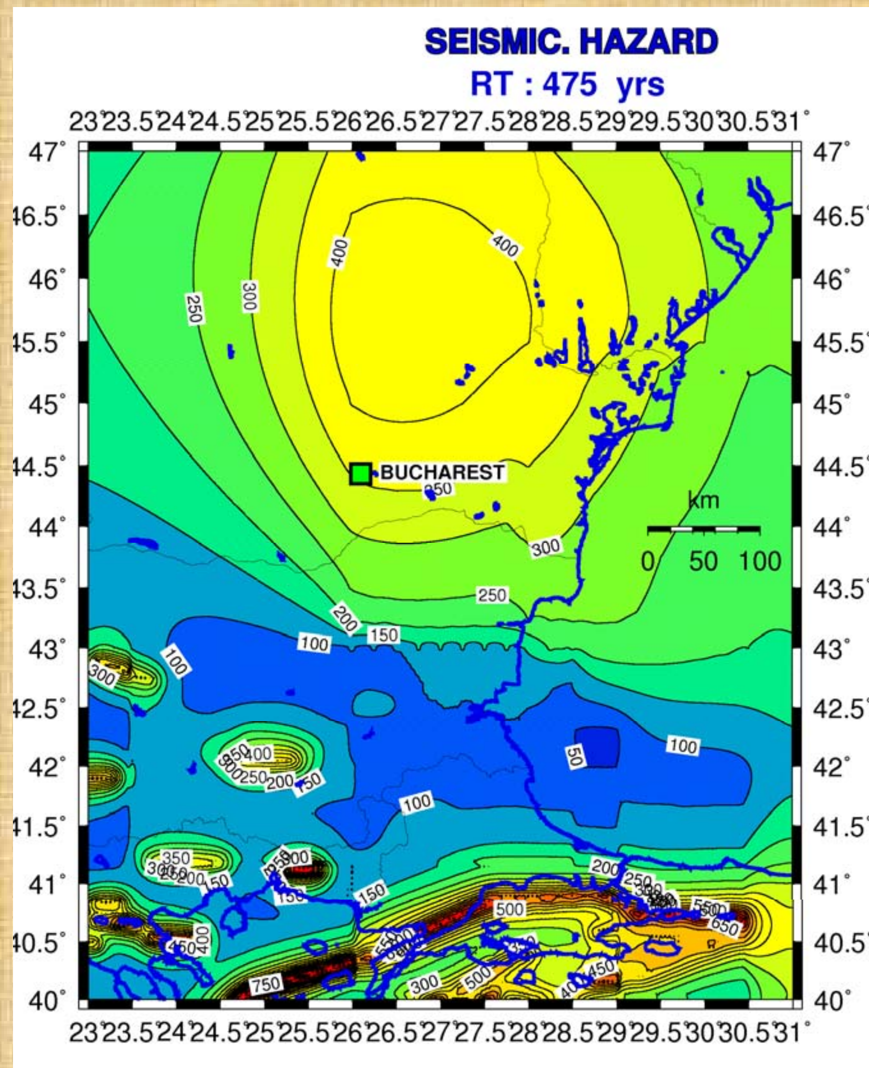

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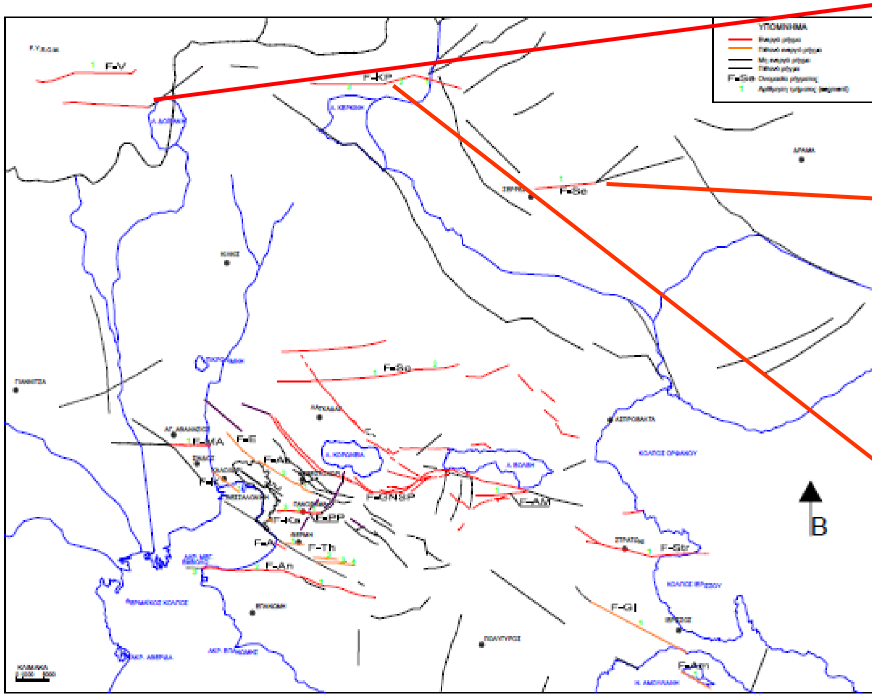
DETERMINISTIC APPROACH

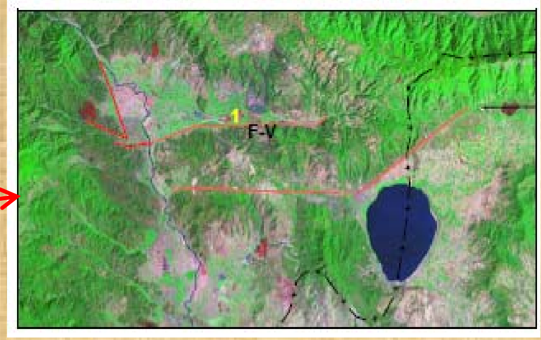
Serres Simulations SGM - Margaris 2013

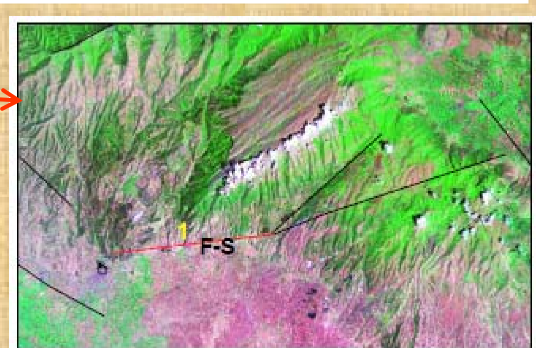
Ενεργά Νεοτεκτονικά Ρήγματα

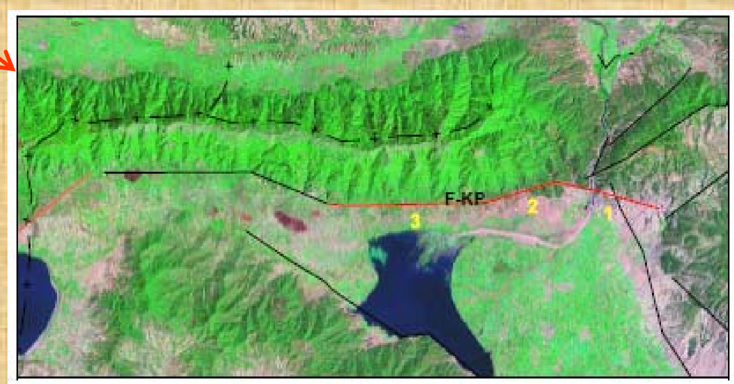
(Pavlidis et al., 2005)



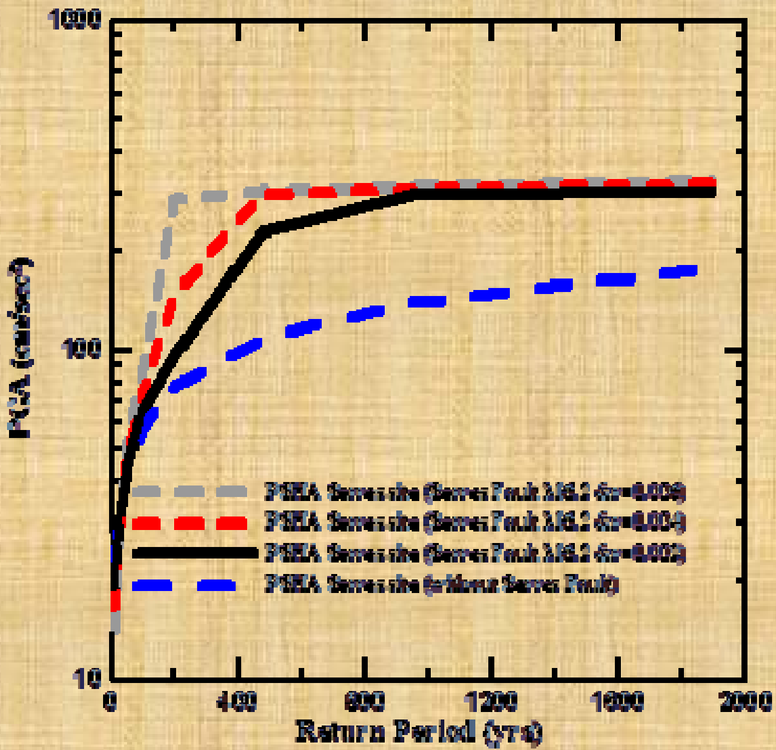
Χάρτης 1: Ενεργά ρήγματα της ευρύτερης περιοχής της Θεσσαλονίκης (F-Str Στρατωνίου, F-Gl Γοματίου–Ιερισσού, F-KP Κερκίνης–Πετριτσίου, F-Th Θέρμης, F-An Ανθεμούντα, F-PP Πυλαίας–Πανοράματος, F-As Ασβεστοχωρίου, F-E Ευκαρπίας, F-A Αεροδρομίου, F-MA Ν. Μεσημβρίας–Αγχίαλου, F-K Καλοχωρίου, F-So Σοχού, F-AM Ν. Απολλωνίας–Ν. Μαδύτου, F-Se Σερρών, F-Am Αμουλιανής, F-V Βαλάντοβο, F-GNSP Γερακαρούς–Νικομιδηνού–Στίβου-Περιστερώνα F-Ka Καλαμαριάς).







Seismic Hazard Deaggregation for Serres (Margaris, 2013)

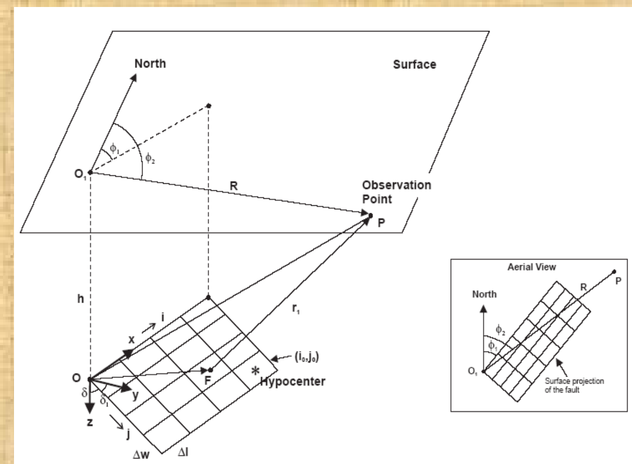


PGA / TR(yrs)	10	25	50	100	200	475	950	1890
PGA (cm/s^2) r=0.02 M6.2	18.58	30.61	44.66	65.17	95.08	225.38	296.20	305.51
PGA r0.02 M6.2 +1σ	41.07	63.63	87.65	124.48	187.83	485.07	551.14	552.81
PGA (cm/s^2) r=0.04 M6.2	15.96	29.53	47.03	74.92	146.86	296.03	305.43	315.06
PGA (cm/s^2) r=0.06 M6.2	14.06	29.12	50.51	87.61	286.12	301.44	311.02	320.84
PGA (cm/s^2) r=0.07 M6.7	13.68	29.46	52.62	93.99	218.52	376.48	480.18	523.72
PGA r0.07 M6.7 +1σ	41.38	68.63	103.01	201.39	453.94	745.01	909.76	1109.56
PGA (cm/s^2) without SF	22.47	32.73	43.51	57.84	76.89	107.90	138.43	176.16
PGA (cm/s^2) Papazachos etal. (1996)	45.30	70.3	95.3	127.5	165.6	220.4	265.7	310.00

Strong Motion Simulations

2. Finite source model

3. (Beresnev and Atkinson, 1997; 1998a; 1998b; 1999; Atkinson and Silva, 1997; 2000, Margaris 2001).



$$f_0 = (y\ z\ /\ \pi)\ \beta_0\ /\ \Delta l$$

$$m_0 = \Delta\sigma\ \Delta l^3$$

$$\log \Delta l = -2.0 + 0.4\ M$$

SERRES

Results for strong motion synthetics

Margaris 2013