ON EARTHQUAKE RISK MITIGATION IN ROMANIA AND IN ALL COUTRIES UNDER STRONG AND DEEP VRANCEA EARTHQUAKES INFLUENCES

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The quality of life and the security of infrastructure (including human services, civil and industrial structures systems, financial infrastructure, information transmission and processing systems) in every nation and in any place are increasingly vulnerable to disasters caused by events that have geologic, atmospheric, hydrologic, and technological origins. Investment of intellectual and material resources to prevent and mitigate such disasters is critical to every sector of our global society.

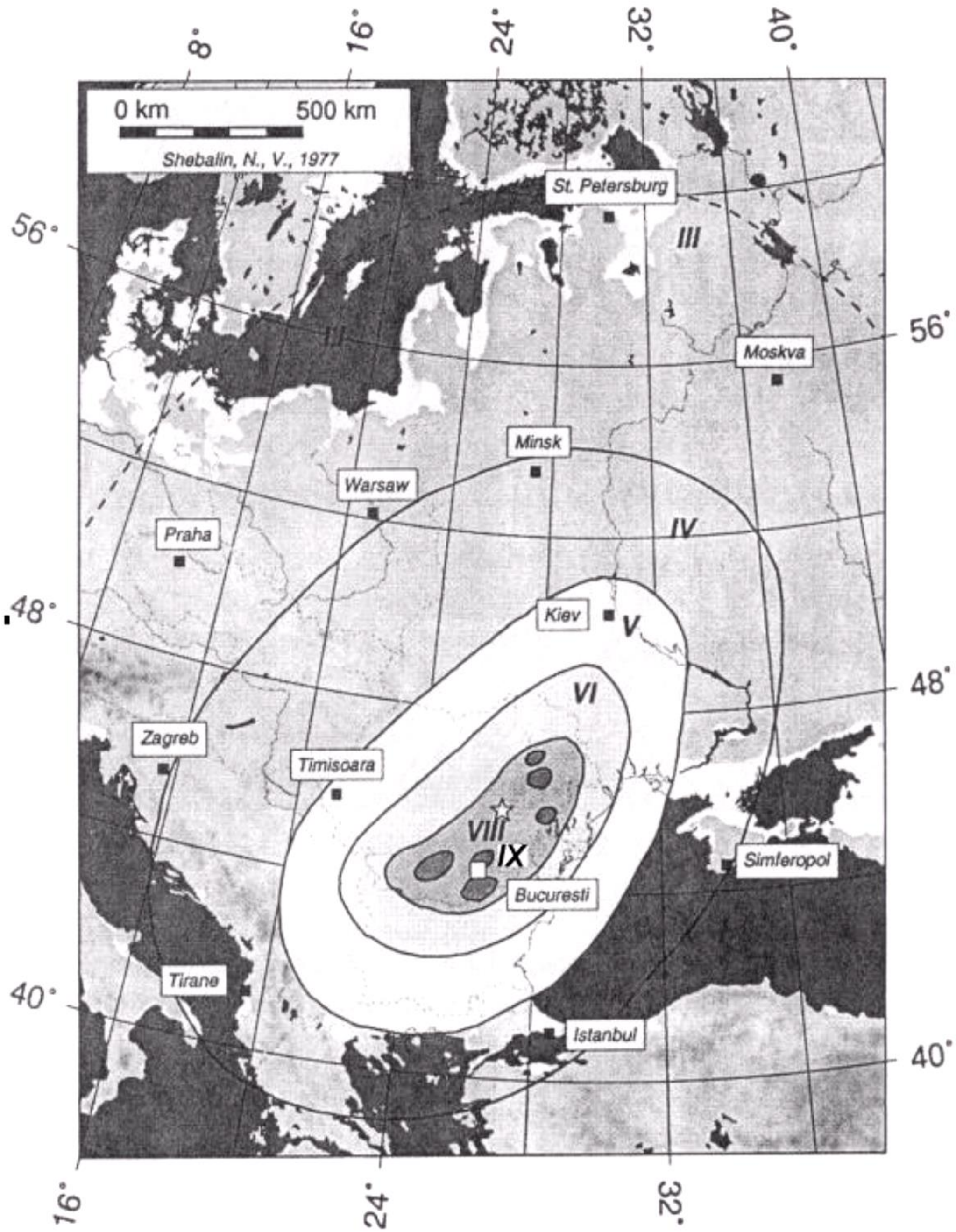
In world, earthquakes are responsible for 15% of total number of events, and 30% of the total damages (P. K. Freeman, Natural Disasters and Poverty,pp-55-61,Disaster Risk Management Series nr.2,The World Bank, Washington, D.C.,2000,Ed.A. Kreimer & M. Arnold).

Sumatra strong Earthquake (M_W =9.4) on December 26,2005:

- **Total damage: $10.73 billion.**
- **Rebuilding costs: $10.375 billion.**
- **Number of people displaced: 2,089,883.**
- **Number of people who lost their livelihoods: 1.5 million.**
- **Number of people killed: at least 380,000.**
- **Ratio of women and children killed to men: 3:1**

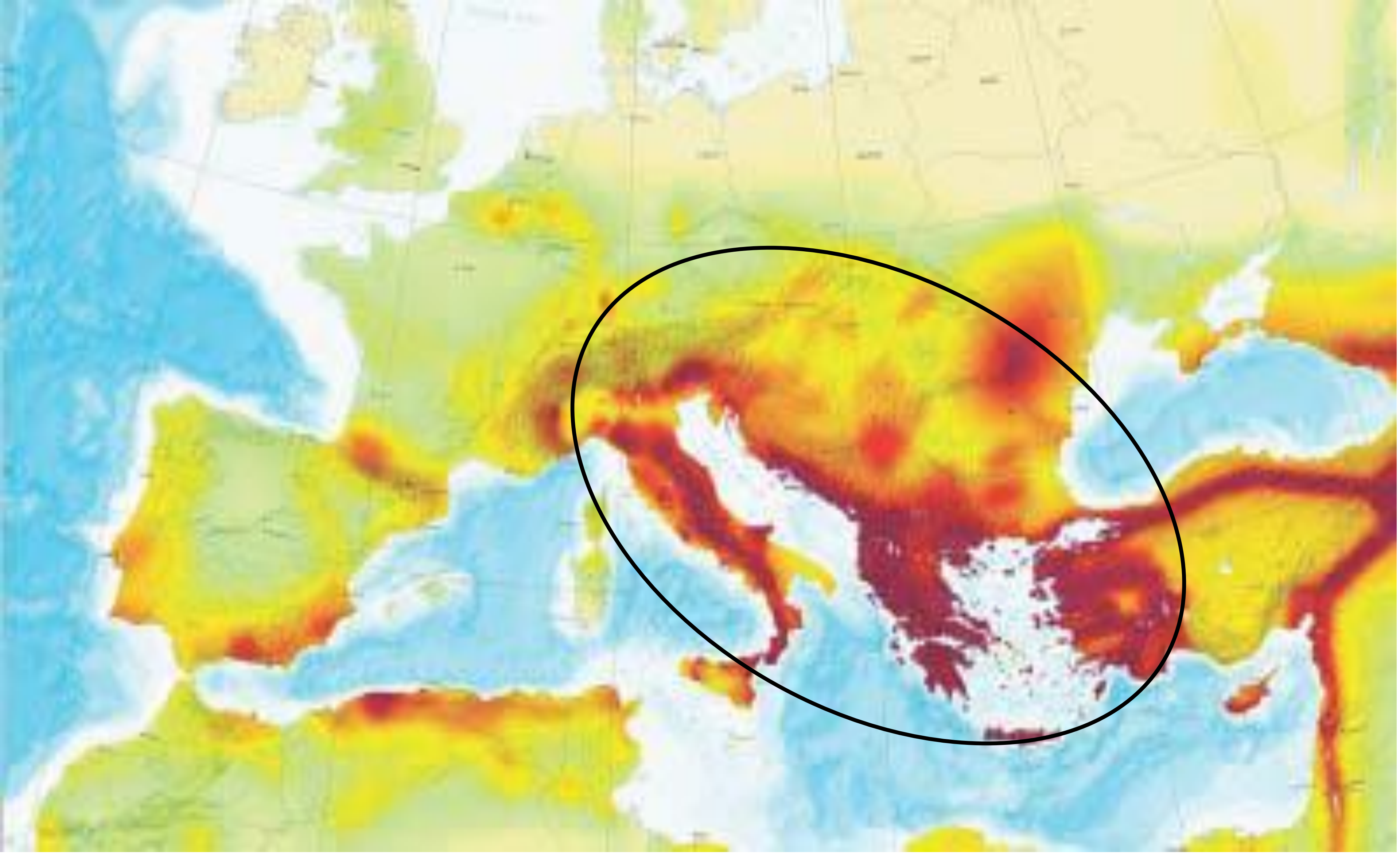
Earthquake risk in Romania

- **Earthquakes represent a risk in many parts of the world, particularly South-eastern of Europe and especially in Romania is awaiting another strong earthquake. Earthquakes in the Carpathian-Pannonia region are confined to the crust, except the Vrancea zone, where earthquakes with focal depth down to 200 km occur;**
- **For example, the ruptured area migrated from 150 km to 180 km (Nov. 10,1940 Vrancea earthquake, Mw =7.7), from 90 to 110 km (March 4, 1977 earthquake, Mw =7.4),from 130 to 150 km (Aug. 30, 1986, Mw = 7.1) and from 70 to 90 km (May 30,1990, Mw =6.9 and May 31,1990,Mw=6.4) depth;**
- **The depth interval between 110 km and 130 km remains not ruptured since 1802, Oct. 26, when it was the strongest earthquake occurred in this part of Central Europe. The magnitude is assumed to be Mw =7.9 - 8.0 and this depth interval is a natural candidate for the next strong Vrancea event;**
- **The strong seismic events originating from Vrancea area can generate the most destructive effects experienced in Romania and Bulgaria, and may seriously affect high risk man-made structures such as nuclear power plants (Cernavoda, Kozloduj etc.), chemical plants, large dams, and pipelines located within a wide area from Central Europe to Moscow or to Rome. More, Vrancea type of seismicity is nowhere else observed on earth.**



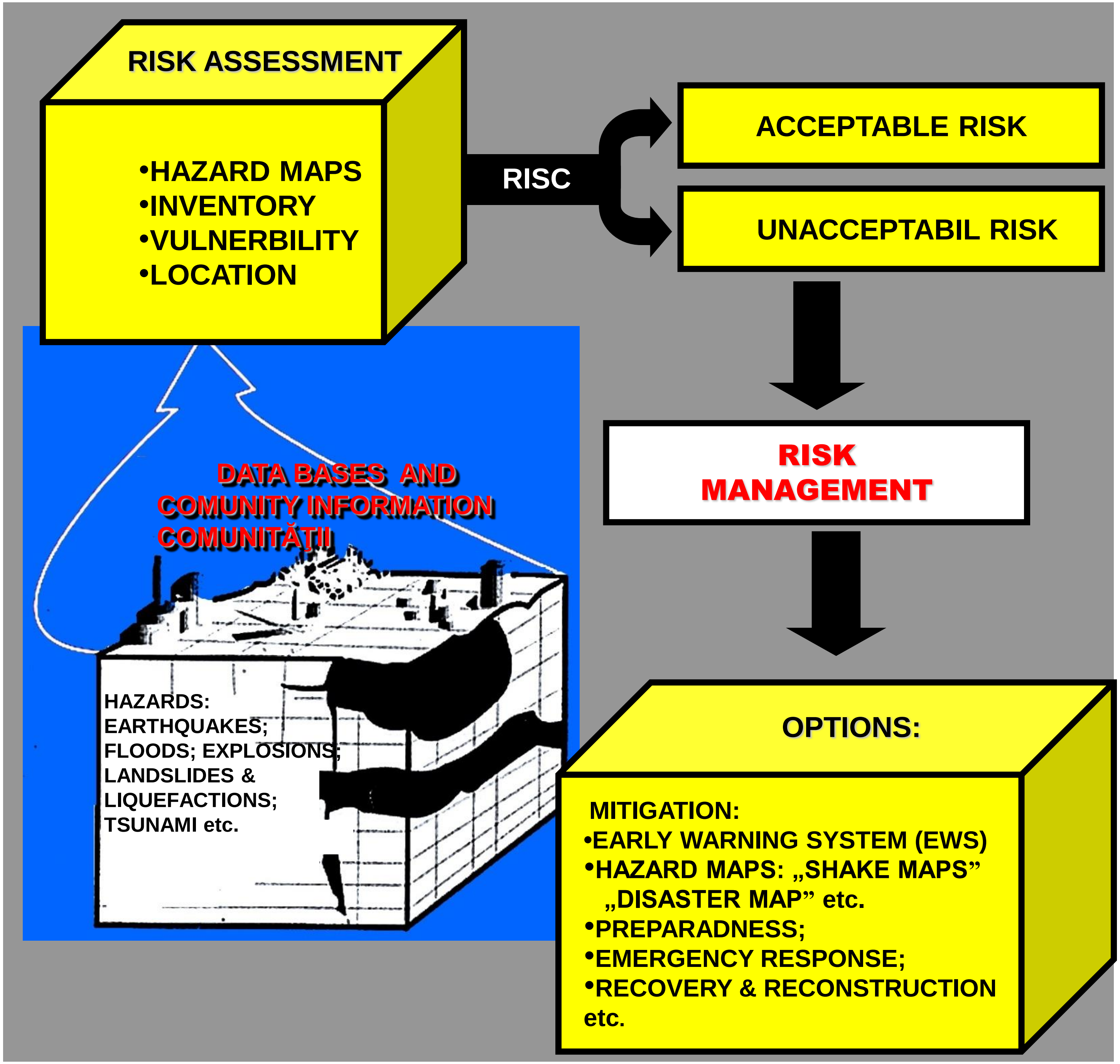
The effect of strong Vrancea earthquakes from Central Europe toMoscow:

1701;M_W=7.4; ?
1738;M_W=7.7;
1802;M_W=7.9;
1838;M_W=7.5;
1940;M_W=7.7;
1977;M_W=7.5 etc.



Seismic hazard map of Europe and surrounding regions. Note the level of the seismic hazard in South Eastern Europe which is the *highest for the whole region*

HOW CAN WE MAKE COOPERATION IN DISASTER RISK MANAGEMENT IN THE BALKAN & SOUTH EAST EUROPE REGION ?



Risk Management

HOW TO REDUCE EARTHQUAKE RISK IN BALKAN AND SOUTH EAST EURIPE REGION FROM TECHNICAL POINT OF VIEW ?

OBJECTIVES:

- ***To promote and encourage scientific and technical cooperation*** between countries of the Balkan region in action aimed at reducing the risks to life and property caused by strong earthquakes in the region;
- ***To spread scientific and technical knowledge*** resulting from the programme, particularly among countries in seismic zones;
- ***Real-time monitoring of earthquake*** from Balkan and South East Europe Region**.** Each partner will have the possibility to rapidly and accurately locate any significant earthquake which occur in its territory. This means the implementation of new digital seismological stations with real time data transmission and real time data processing. Real time data exchange between partners will be set up to ensure that each partner is able to locate events in border regions;

- ***Specific Actions to <u>Mitigate Seismic Risk</u>.***

  Romanian Government Low nr.372/March 18,2004 :"The National Program of Seismic Risk Management ":

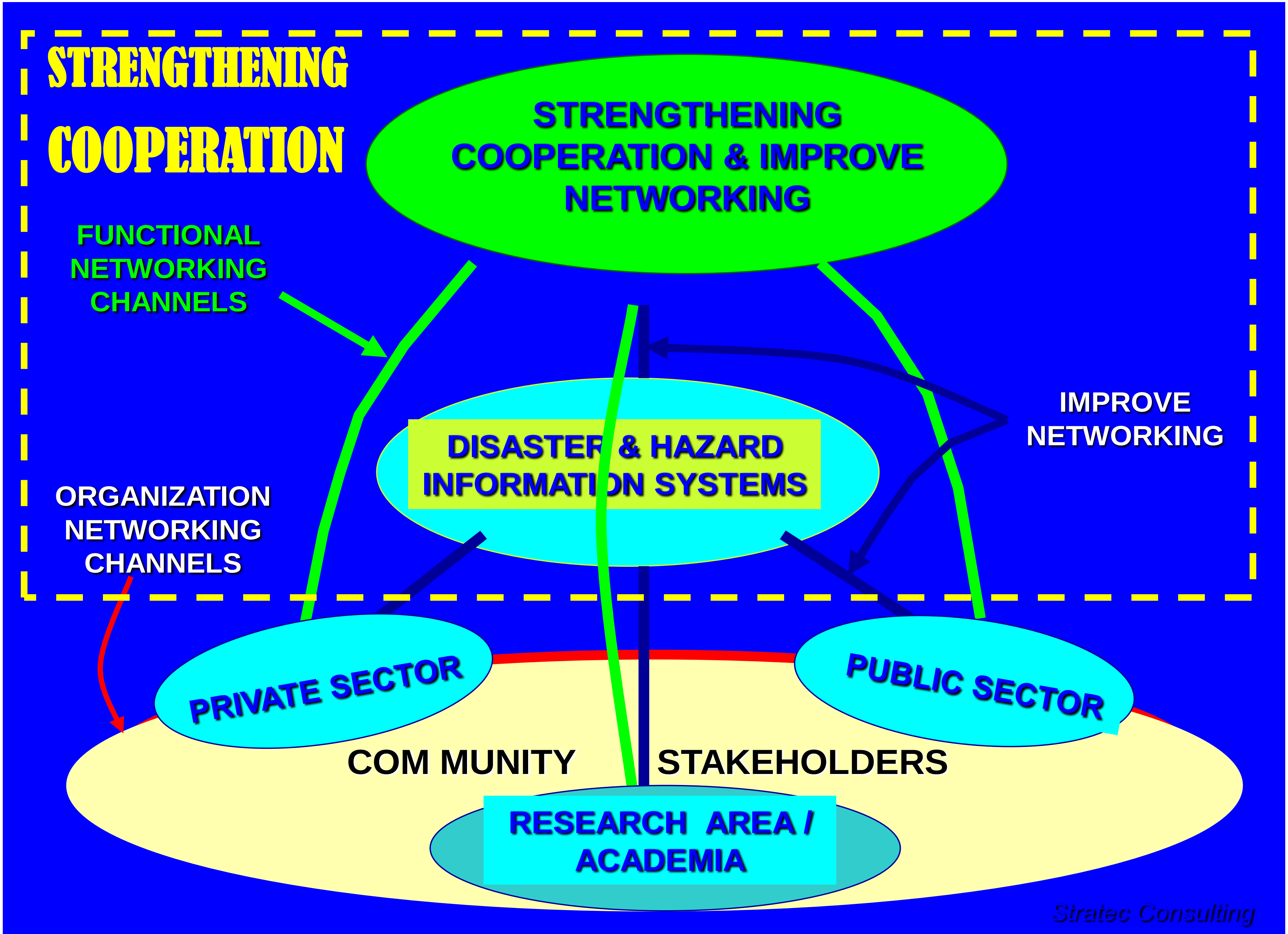
  a). ***Early warning system (EWS) for industrial facilities and other installations of national interest to strong intermediary earthquakes;***

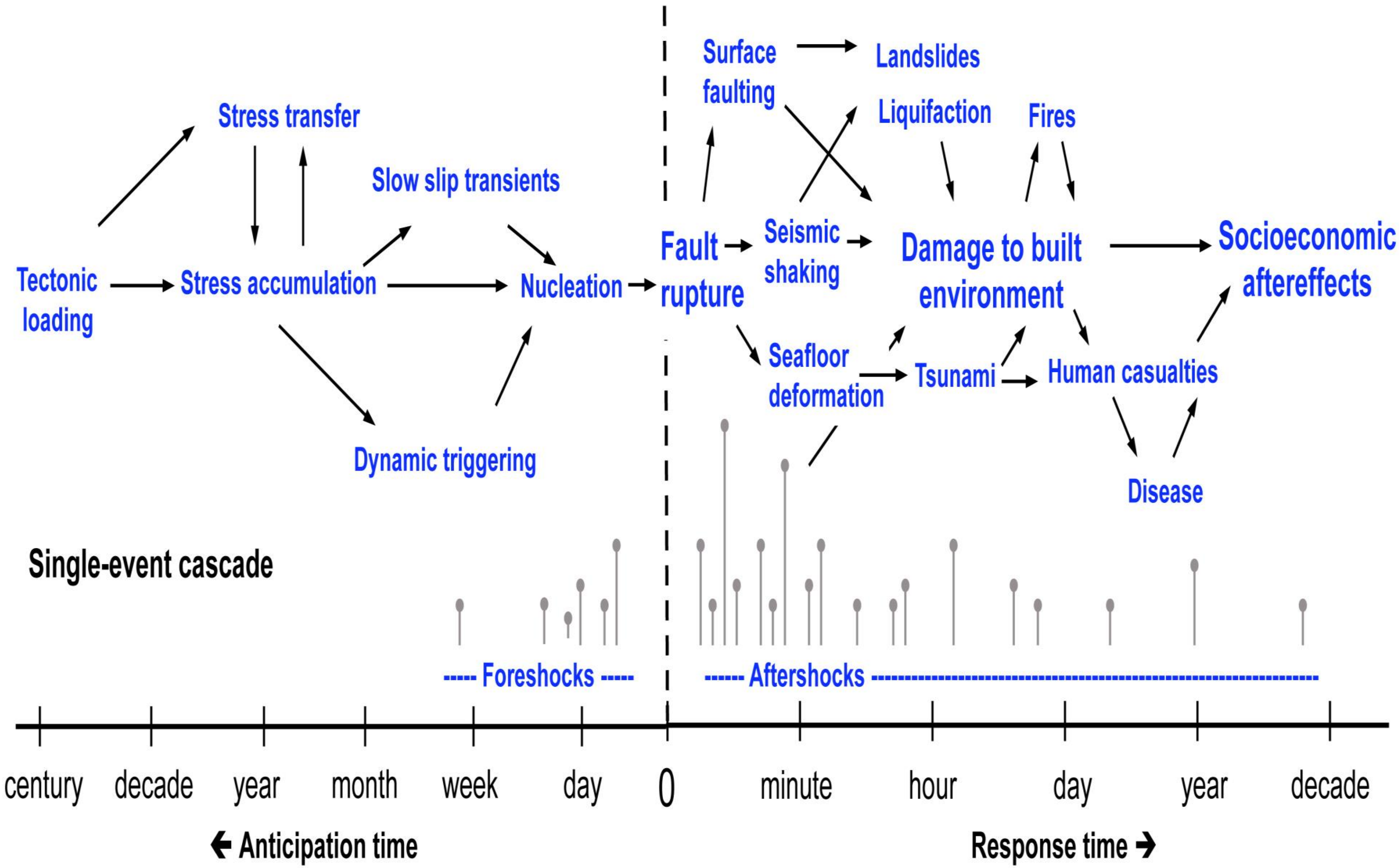
  b). ***Seismic hazard map;***

  c). ***Seismic microzonation maps of large populated cities as part of mitigation the impact of strong earthquakes to large populated areas;***

  d). Shake map **for strong Vrancea earthquakes**

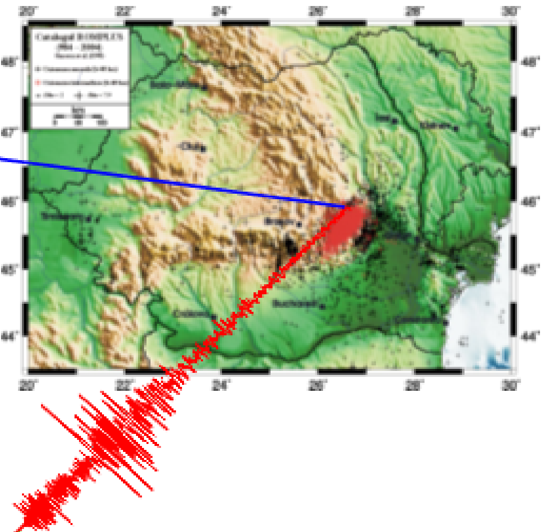
  e). Seismic tomography of special structures like dams for avoiding catastrophes etc.

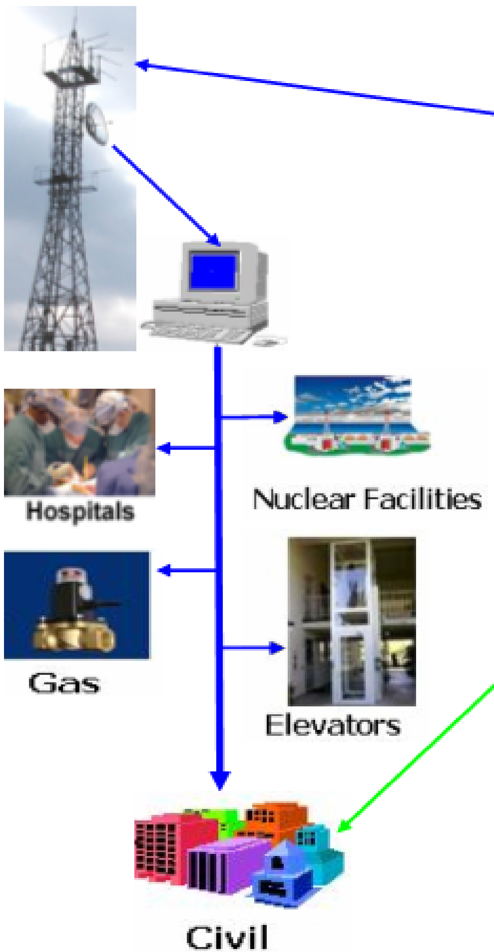

STRENGTHENING COOPERATION
STRENGTHENING COOPERATION & IMPROVE NETWORKING
FUNCTIONAL NETWORKING CHANNELS
DISASTER & HAZARD INFORMATION SYSTEMS
IMPROVE NETWORKING
ORGANIZATION NETWORKING CHANNELS
PRIVATE SECTOR
PUBLIC SECTOR
COM MUNITY STAKEHOLDERS
RESEARCH AREA / ACADEMIA
Stratec Consulting



Early Waning System(EWS). Anticipation & Response Time

SAFER-FP6 & REAKT –FP7 Projects





National Institute for Earth Physics, Romania
Geophysical Institute, Karlsruhe University, Germany

EARLY WARNING SYSTEM (EWS)

30 seconds

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Bucharest-Magurele,
12 Calugareni Str.
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Telephone: +40 21 4050670
Fax: +40 21 4050673
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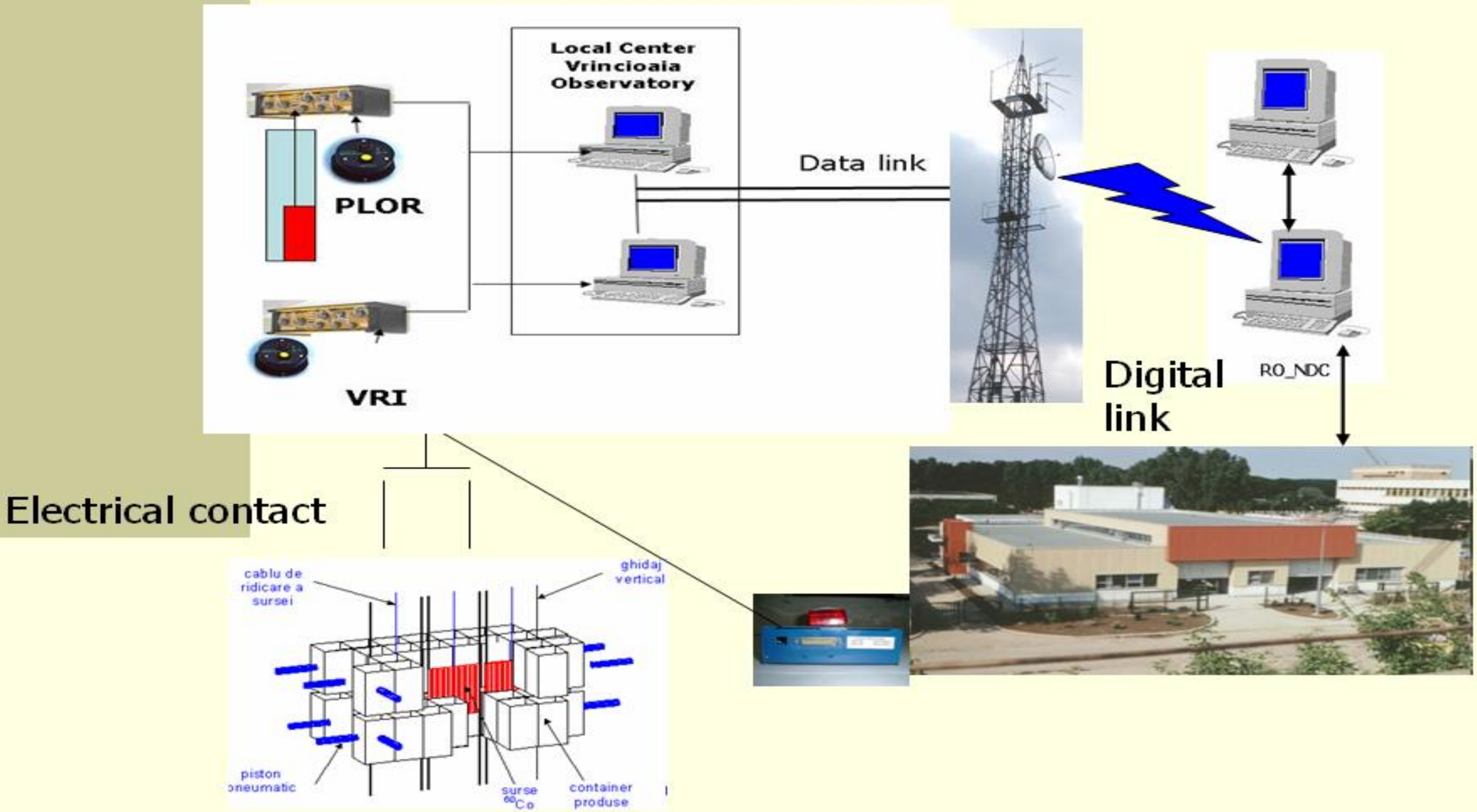
Web : http://www.infp.ro

Early Warning System, in real time, for deep strong Vrancea earthquakes

Shutdown Cobalt-60 nuclear radiation source in safe position at IFIN-HH Bucharest



EWS for an irradiator nuclear installation from Bucharest-Măgurele

UNIUNEA EUROPEANĂ
FONDUL EUROPEAN PENTRU DEZVOLTARE REGIONALA

GUVERNUL ROMANIEI

GUVERNUL BULGARIEI

ROMÂNIA - BULGARIA
Program de Cooperare Transfrontalieră

Project DACEA:

„DAnube Cross-border system for Earthquakes Alert”

(August 10,2010-February 10,2013

EU-CROSS BORDER Project)

Prof. Gheorghe Marmureanu- Project Manager

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

GOVERNMENT OF ROMANIA

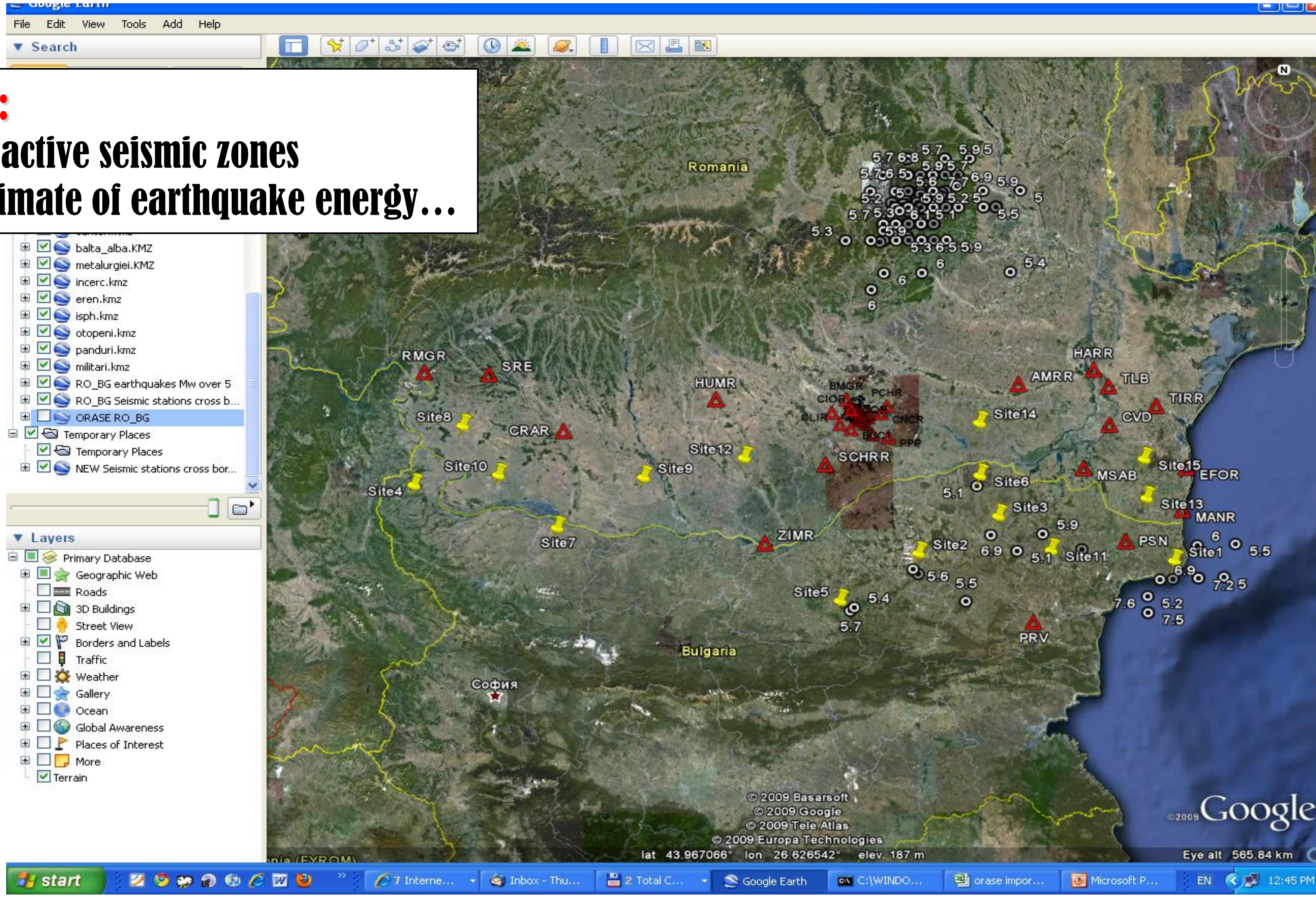
GOVERNMENT OF BULGARIA

ROMANIA - BULGARIA Cross Border Cooperation Programme

Common borders. Common solutions.

PURPOSE :

- Cover all active seismic zones
- Quick estimate of earthquake energy…

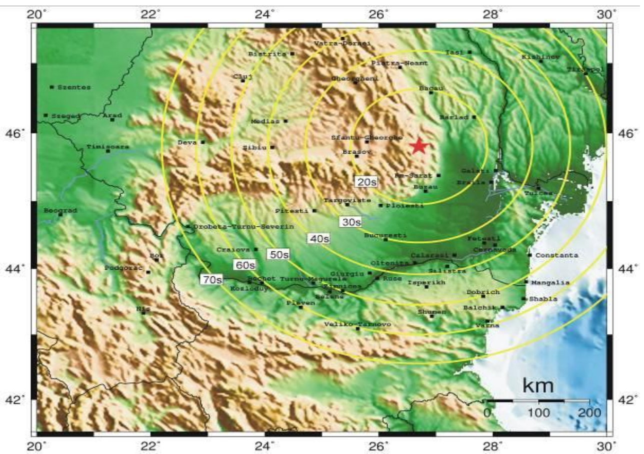


NEW SEISMIC STATIONS IN CROSS BORDER AREA !

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
GOVERNMENT OF ROMANIA
GOVERNMENT OF BULGARIA
ROMANIA - BULGARIA Cross Border Cooperation Programme
Common borders. Common solutions.

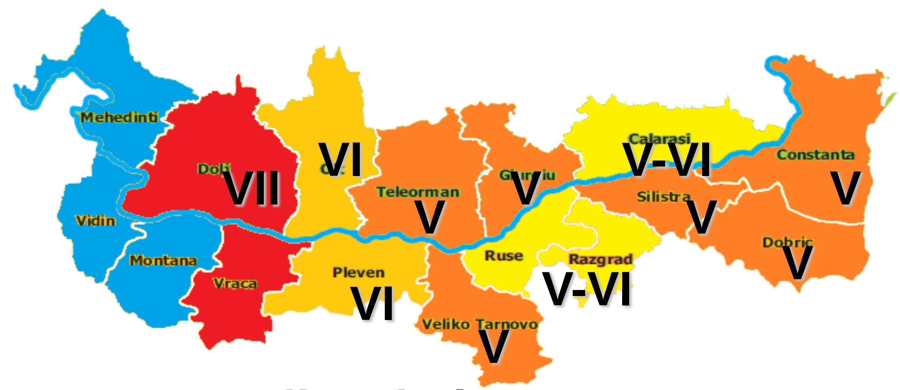
DAnube Cross-border system for Earthquakes Alert"(DACEA) (Aug.10,2010-Febr.10.2013)

Earthquake Early Warning System type of products example



P and S wave Travel time

Products accesible until S wave arrive in site.



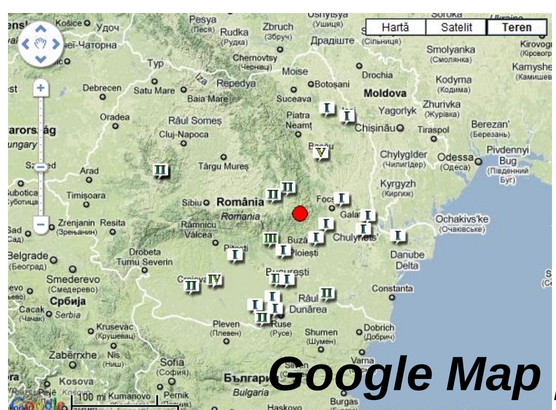
Predicted Alert Map

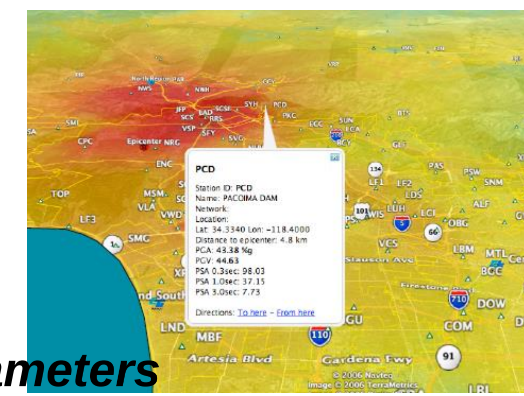
<u>Time Alert</u>

Ex. Vrancea eq.
30 seconds before S Wave arrive in site

<u>Users</u>

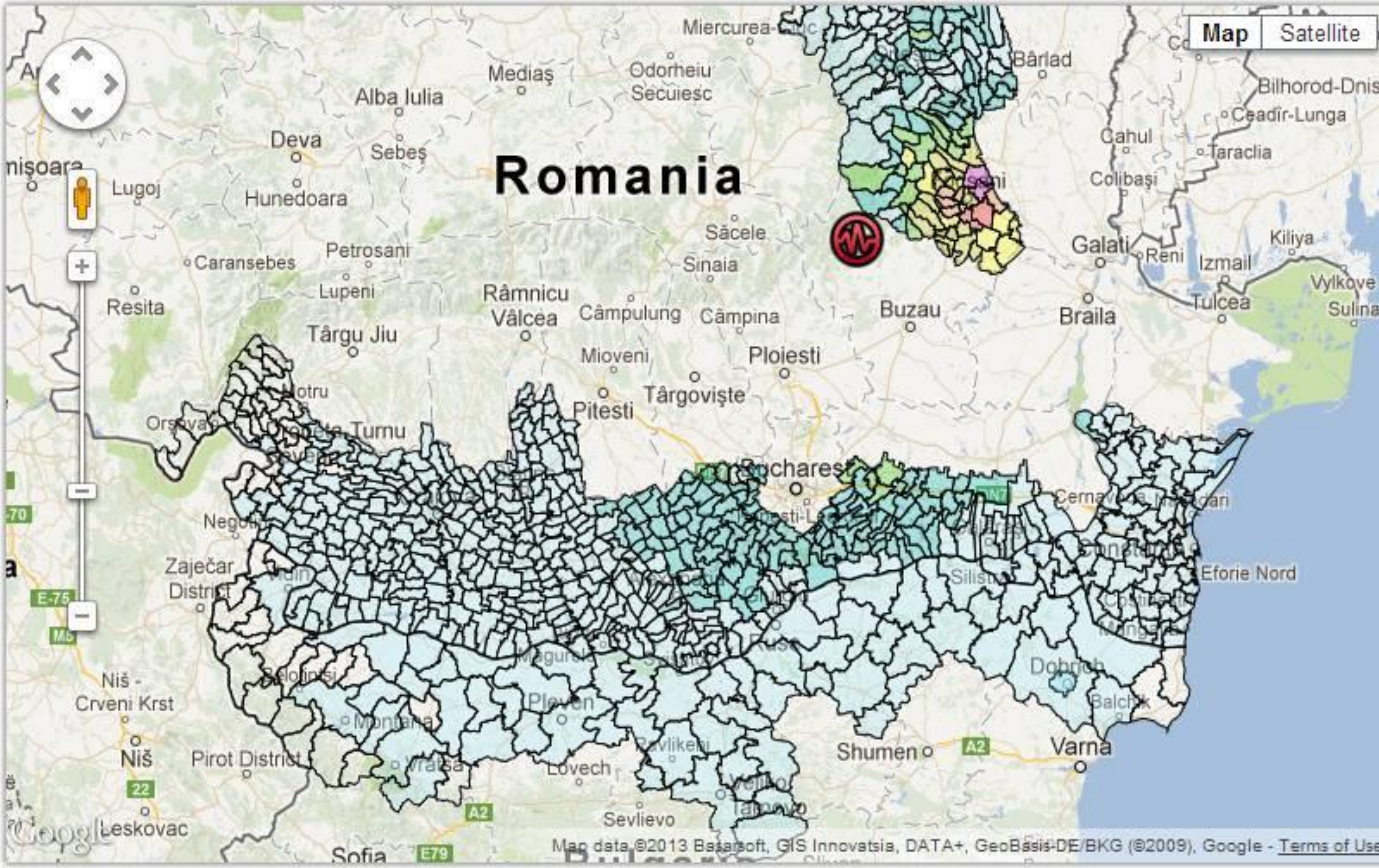
IES, CP, CJ, Infrastr. Municipatities

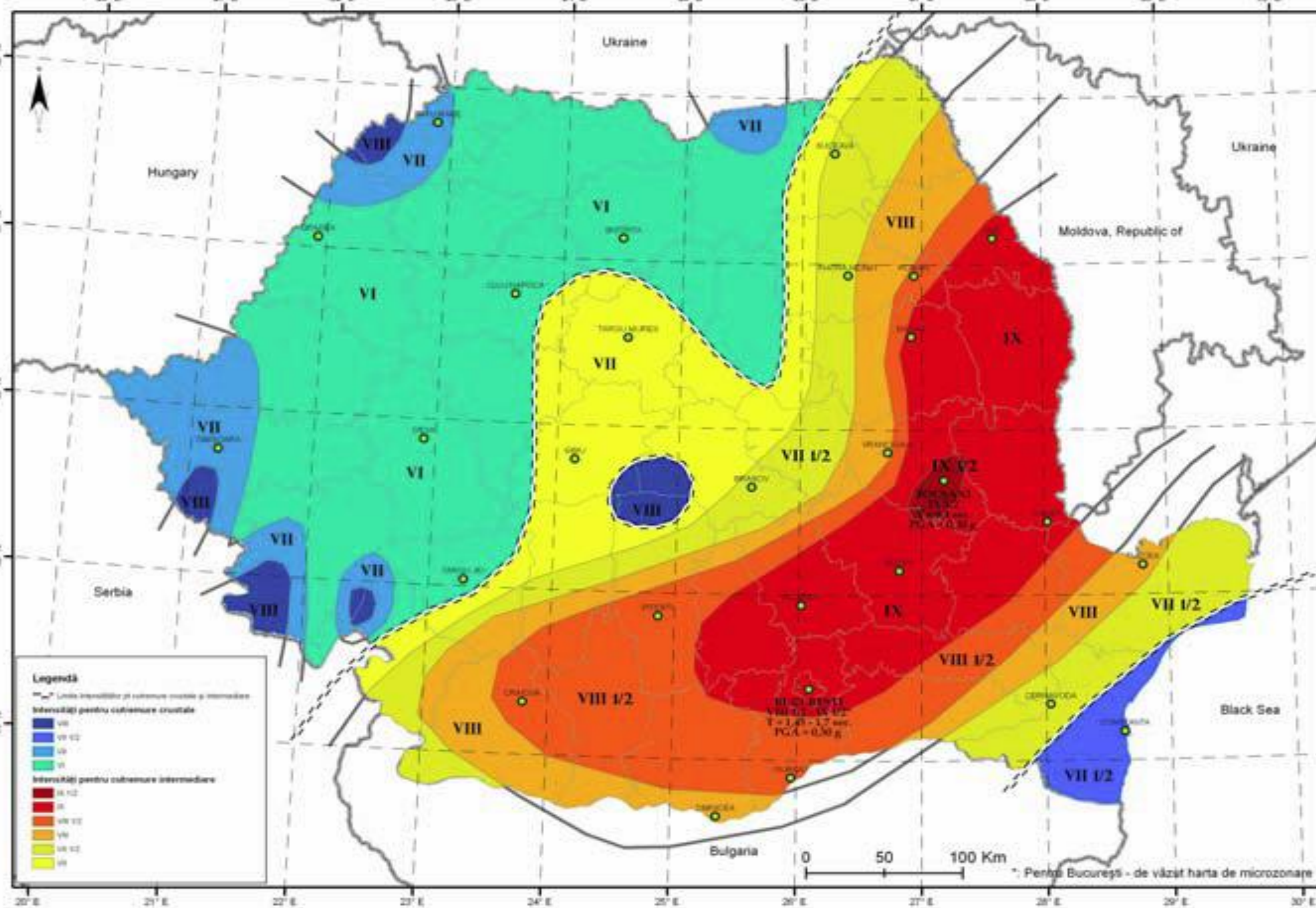




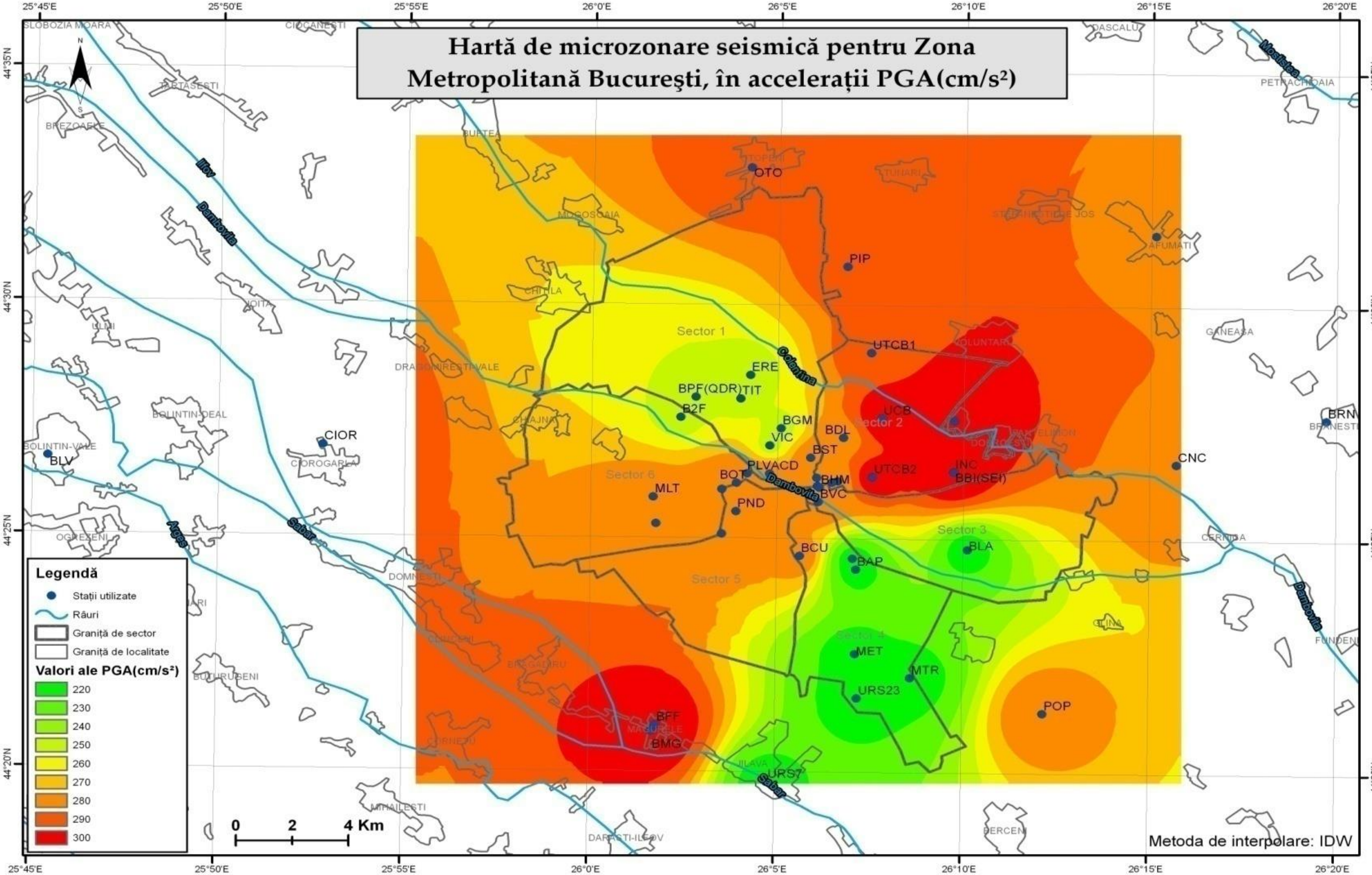
Google Map parameters

Estimates of the *vulnerability of buildings*, for a scenario earthquake VR1986 - (SELENA)

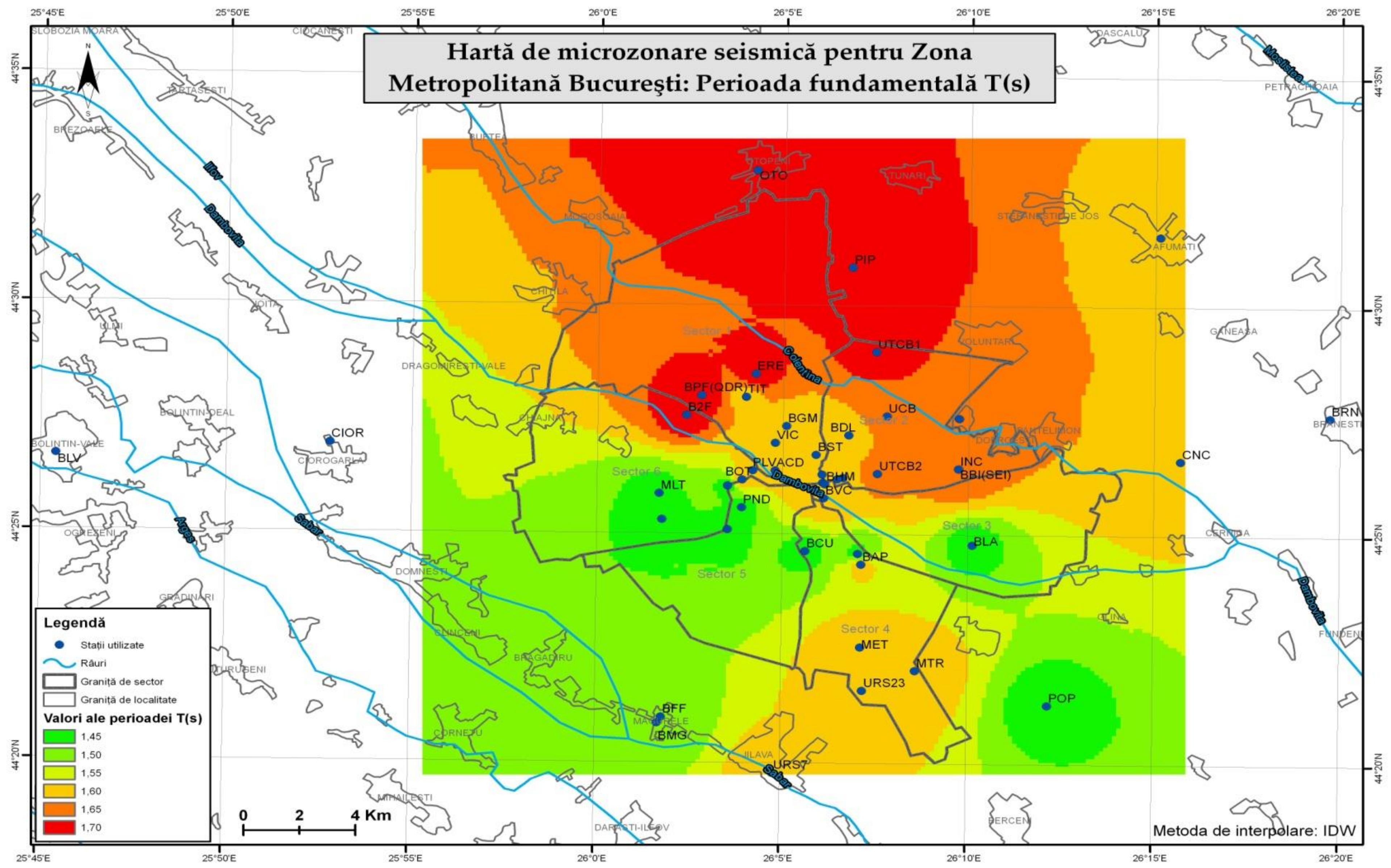




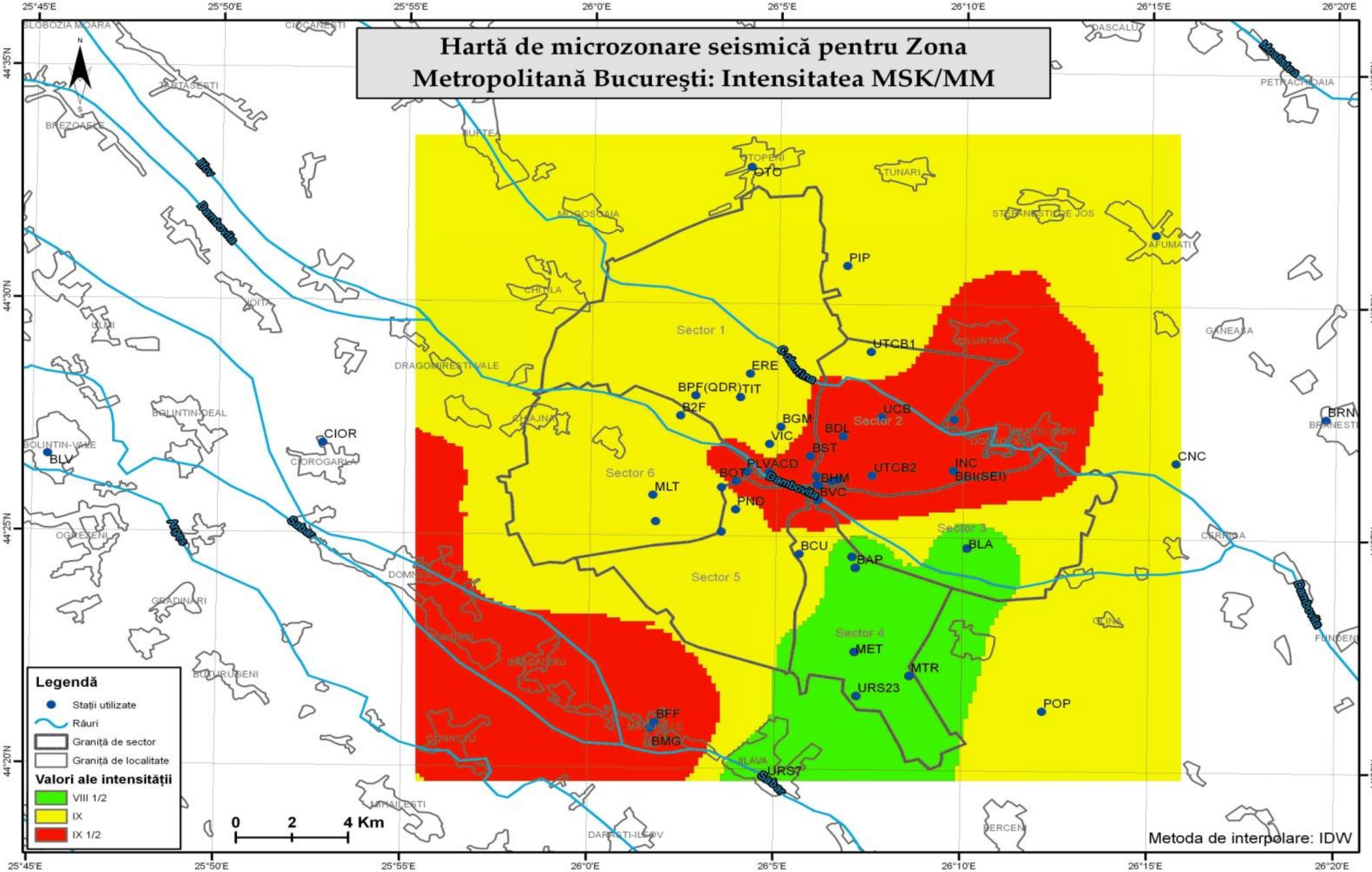
The isoseismal map of the maximum credible Vrancea earthquake or maximum probable Vrancea earthquake (*Mw* = 7.8-7.9) with MSK and MMI intensities of IX½ in epicenter area and Bucharest



Seismic zoning map of Bucharest metropolitan area with maximum accelerations (PGA) in cm/s² for the maximum possible Vrancea earthquake with magnitude $M_{GR} = 7.5$ ($M_W = 7.8$-7.9).



Seismic zoning map of Bucharest metropolitan area with fundamental periods of soils, T(s) for the maximum possible Vrancea earthquake with magnitude M_{GR} =7.5(M_W=7.8-7.9).



Seismic zoning map of the metropolitan area of Bucharest in intensity MSK / MMI for the maximum possible Vrancea earthquake with magnitude M_{GR} =7.5 (M_W=7.8-7.9).

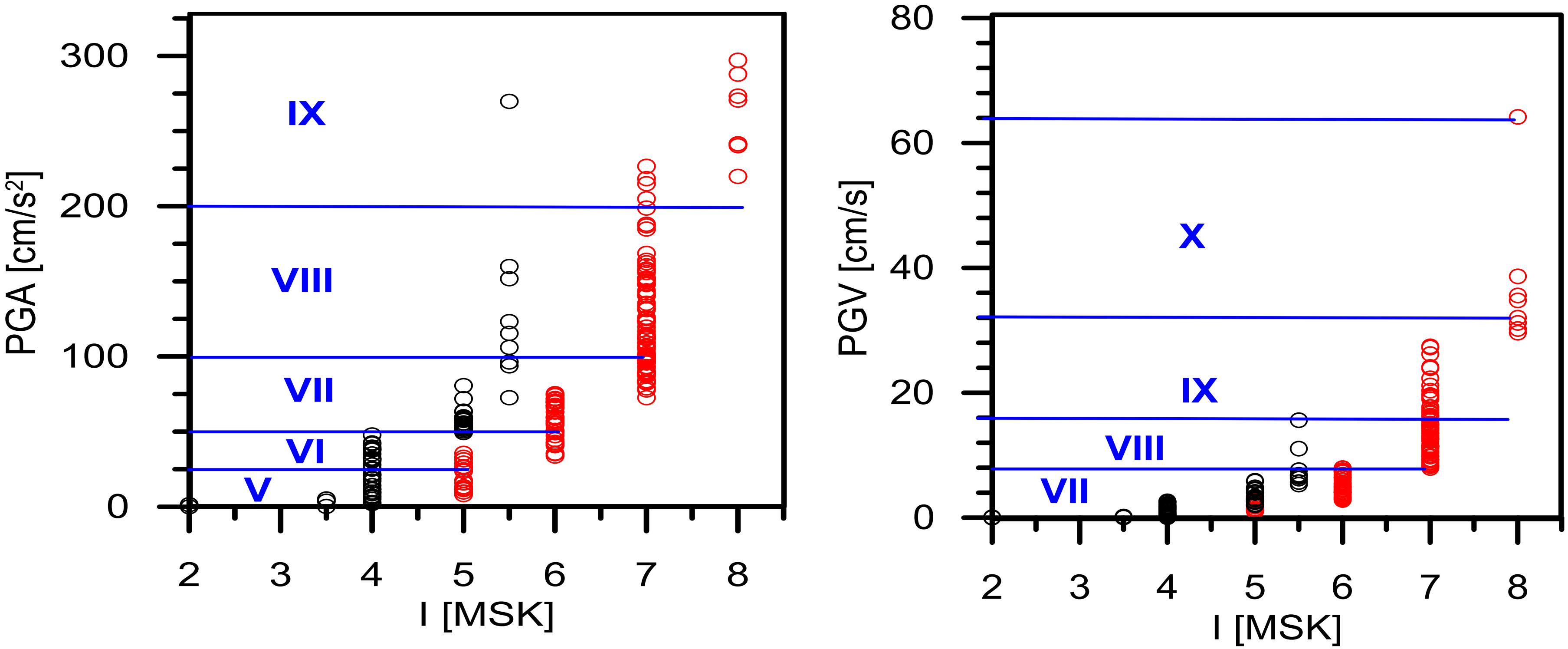
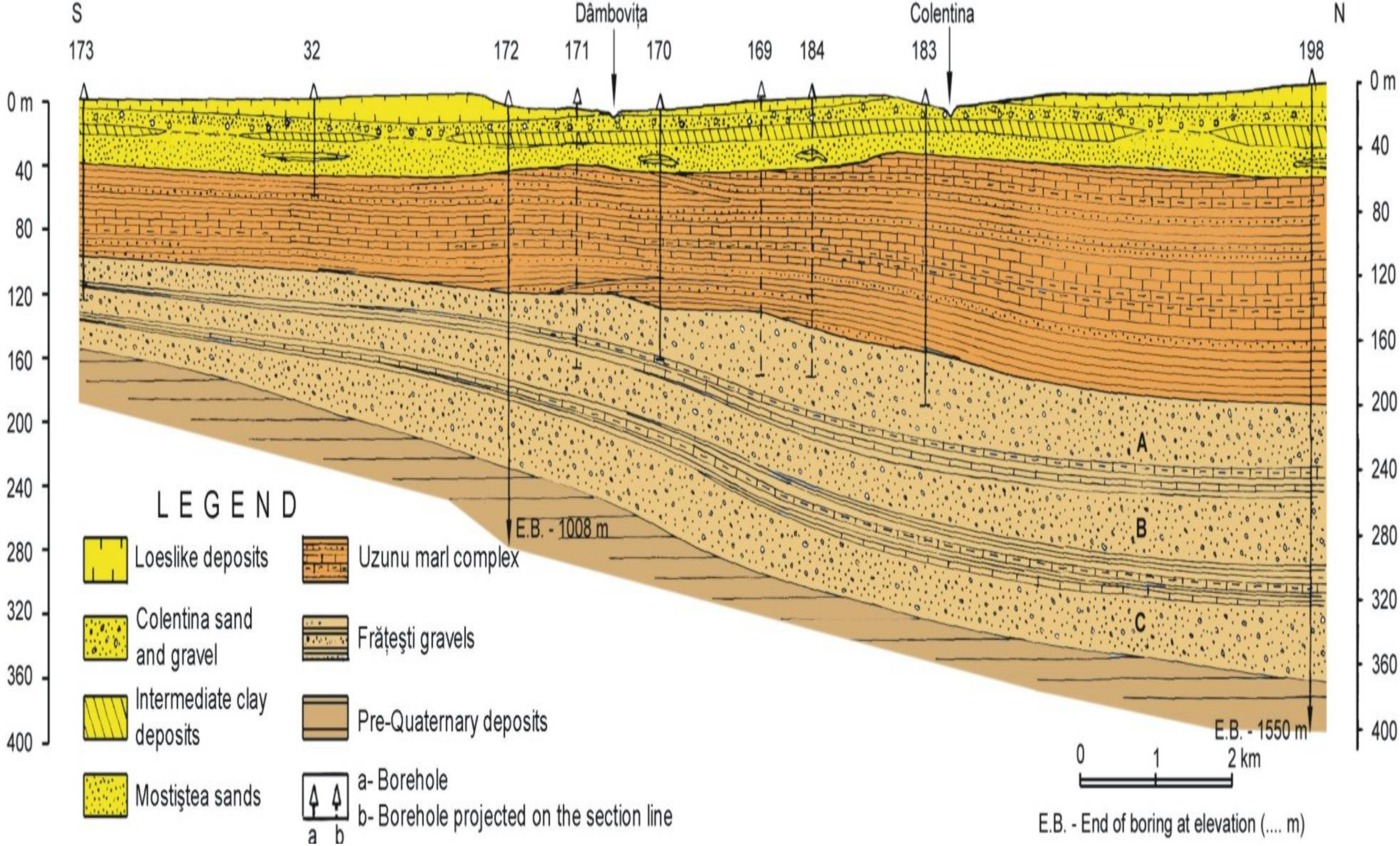


Figure 1.The disperse of PGA value with intensity I(MSK)

In our studies of correlation between macroseismic intensity(I) and **potential of destruction**(physical quantities) by using Pearson coefficient(-1<r < 1) we wanted to find the link between two variables determined independently, that are, MSK/MMI intensity and PGA, PGV or PGD. From Figure 1 we can see the dispersion of PGA values Person coefficients(r) with macroseimic intensity(I): with read for M_W>6.0; with black for M_W for Vrancea earthquake VR2004 (M_W=5.9).With blue color are values by using Medvedev conversion. Records from last earthquakes, which didn't produce any notable damages, are larger than values recorded to earthquakes with M_W>6.0. The ***nonlinear behavior of soils*** is the real reason of these discrepancies.



The geological structure under Bucharest. Isobars are generally oriented East-West with slope of 8‰ down from South to North. In the same direction , the thickness of layers becomes larger.

Cernavoda NPPlant Seismic Station, **E-W comp . ;Φ =44.340; λ=28.030** ***Table 1***

Earthquake	a_{max} (cm/ss) recorded	(Sa)max (β=5%)	SAF	„c”	Sa*(g)	a*(g)	%
Aug.30,1986,Mw=7.1	62.78	256 cm/ss	4.0777	1.420	363.52	89.14	42.0%
May 30,1990,Mw=6.9	100.06	475 cm/ss	4.7471	1.219	579.02	121.97	21.9%
May 31,1990,Mw-6.4	49.73	288 cm/ss	5.7912	1.000	288.00	49.73	-

Bucharest-INCERC Seismic Station, **N-S Component.; Φ =44.442; λ=26.105** ***Table 2***

Earthquake	a_{max}(cm/ss) (recorded)	(Sa) max (β=5%)	SAF	„c”	Sa*(g)	a*(g)	%
March 4,1977,Mw=7.4	206.90	650 cm/ss	3.14	1.322	859.3	273.5	32.2%
Aug. 30,1986, Mw=6.9	96.96	255 cm/ss	2.62	1.583	403.6	153.4	58.3%
May 30,1990, Mw-6.4	66.21	275 cm/ss	4.15	1.000	275.0	66.2	-

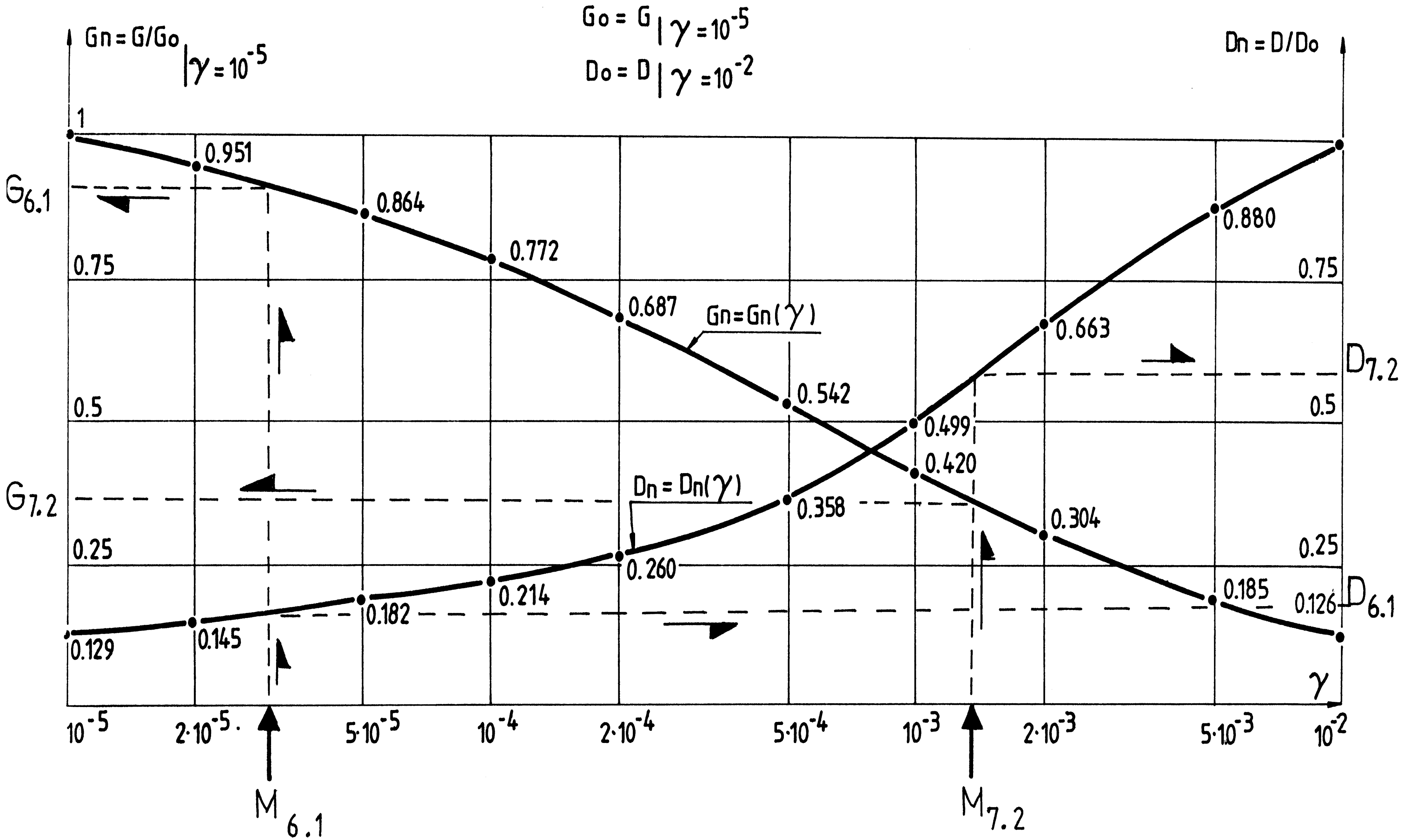
Strong Nonlinear behavior of soils during of strong and deep Vrancea earthquakes in extra-Carpathian area !

Bacau Seismic Station, **E-W comp . Φ = 46.567; λ=26.900** ***Table 3***

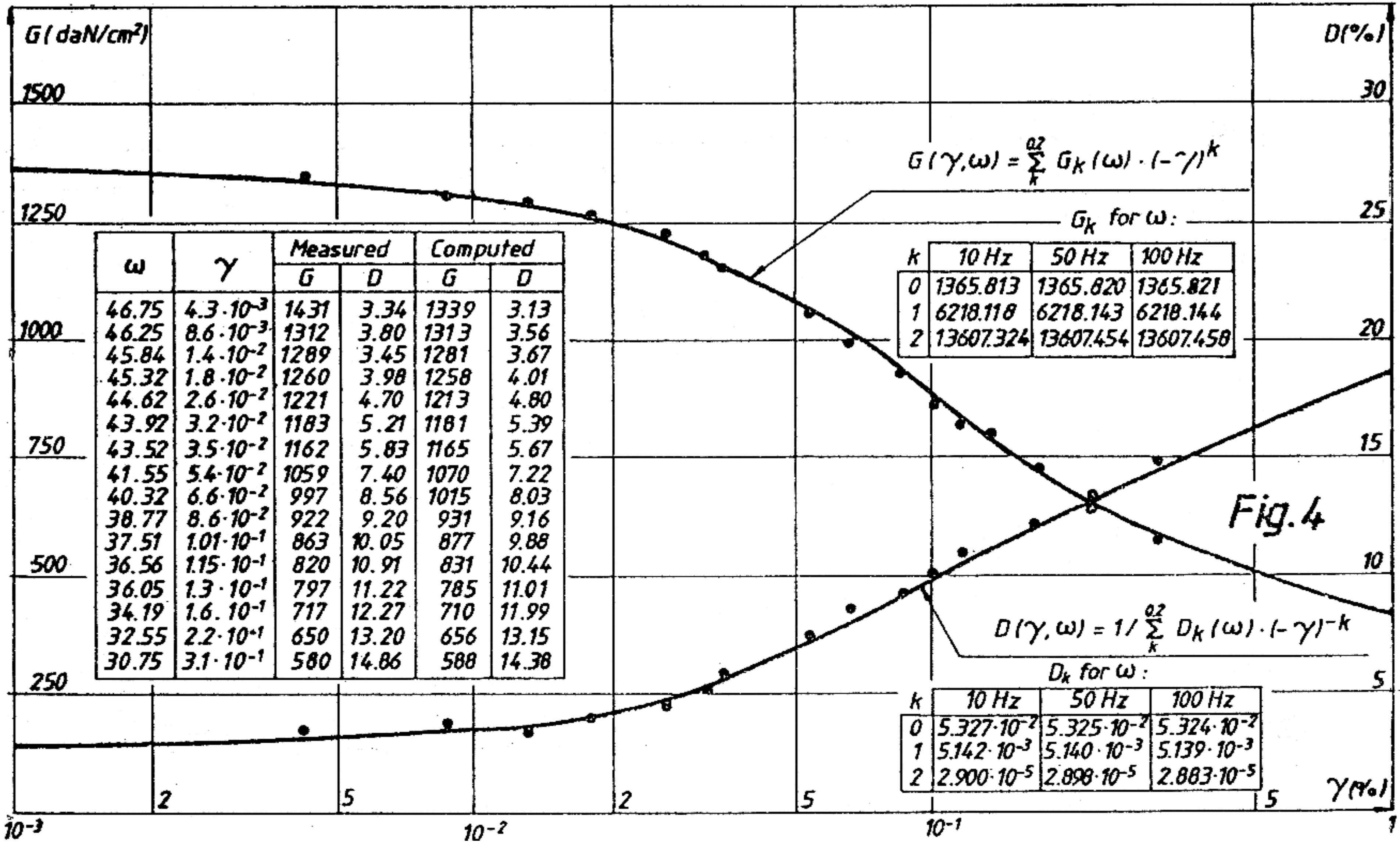
Earthquake	a_{max} (cm/ss) recorded	$(Sa)_{max}$ (β=5%)	SAF	„c”	Sa*(g)	a*(g)	%
Aug.30,1986,Mw=7.1	**72.20**	**292 cm/ss**	**4.0443**	**1.457**	**425.44**	**105.19**	**45.7%**
May 30,1990,Mw=6.9	**132.43**	**684 cm/ss**	**5.1649**	**1.141**	**780.44**	**151.10**	**14.1%**
May 31,1990,Mw=6.4	**63.07**	**372 cm/ss**	**5.8942**	**1.000**	**372.00**	**63.07**	**-**

Bucharest-Metalurgiei Seismic Station, **N127W Comp.; Φ =44.376; λ=26.119** ***Table 4***

Earthquake	a_{max}(cm/ss) (recorded)	(Sa) max (β=5%)	SAF	„c”	Sa*(g)	a*(g)	%
Aug.30,1986, Mw=7.1	**71.07**	**220 cm/ss**	**3.06**	**1.483**	**326.26**	**105.39**	**48.3%**
May 30,1990, Mw=6.9	**55.40**	**220 cm/ss**	**3.97**	**1.143**	**251.46**	**63.32**	**14.3%**
May 31,1990, Mw=6.4	**12.10**	**55 cm/ss**	**4.54**	**1.000**	**55.00**	**12.10**	**-**



The variation of *dynamic torsion modulus function (G, daN/cm2*) and *torsion damping function (G%)* of specific strain (γ%) for *sand and gravel samples with normal humidity obtained in Hardin & Drnevich resonant columns (USA patent) from* NIEP, Laboratory of Earthquake Engineering. Normalized values.



ω	γ	Measured G	Measured D	Computed G	Computed D
46.75	$4.3\cdot10^{-3}$	1431	3.34	1339	3.13
46.25	$8.6\cdot10^{-3}$	1312	3.80	1313	3.56
45.84	$1.4\cdot10^{-2}$	1289	3.45	1281	3.67
45.32	$1.8\cdot10^{-2}$	1260	3.98	1258	4.01
44.62	$2.6\cdot10^{-2}$	1221	4.70	1213	4.80
43.92	$3.2\cdot10^{-2}$	1183	5.21	1181	5.39
43.52	$3.5\cdot10^{-2}$	1162	5.83	1165	5.67
41.55	$5.4\cdot10^{-2}$	1059	7.40	1070	7.22
40.32	$6.6\cdot10^{-2}$	997	8.56	1015	8.03
38.77	$8.6\cdot10^{-2}$	922	9.20	931	9.16
37.51	$1.01\cdot10^{-1}$	863	10.05	877	9.88
36.56	$1.15\cdot10^{-1}$	820	10.91	831	10.44
36.05	$1.3\cdot10^{-1}$	797	11.22	785	11.01
34.19	$1.6\cdot10^{-1}$	717	12.27	710	11.99
32.55	$2.2\cdot10^{+1}$	650	13.20	656	13.15
30.75	$3.1\cdot10^{-1}$	580	14.86	588	14.38

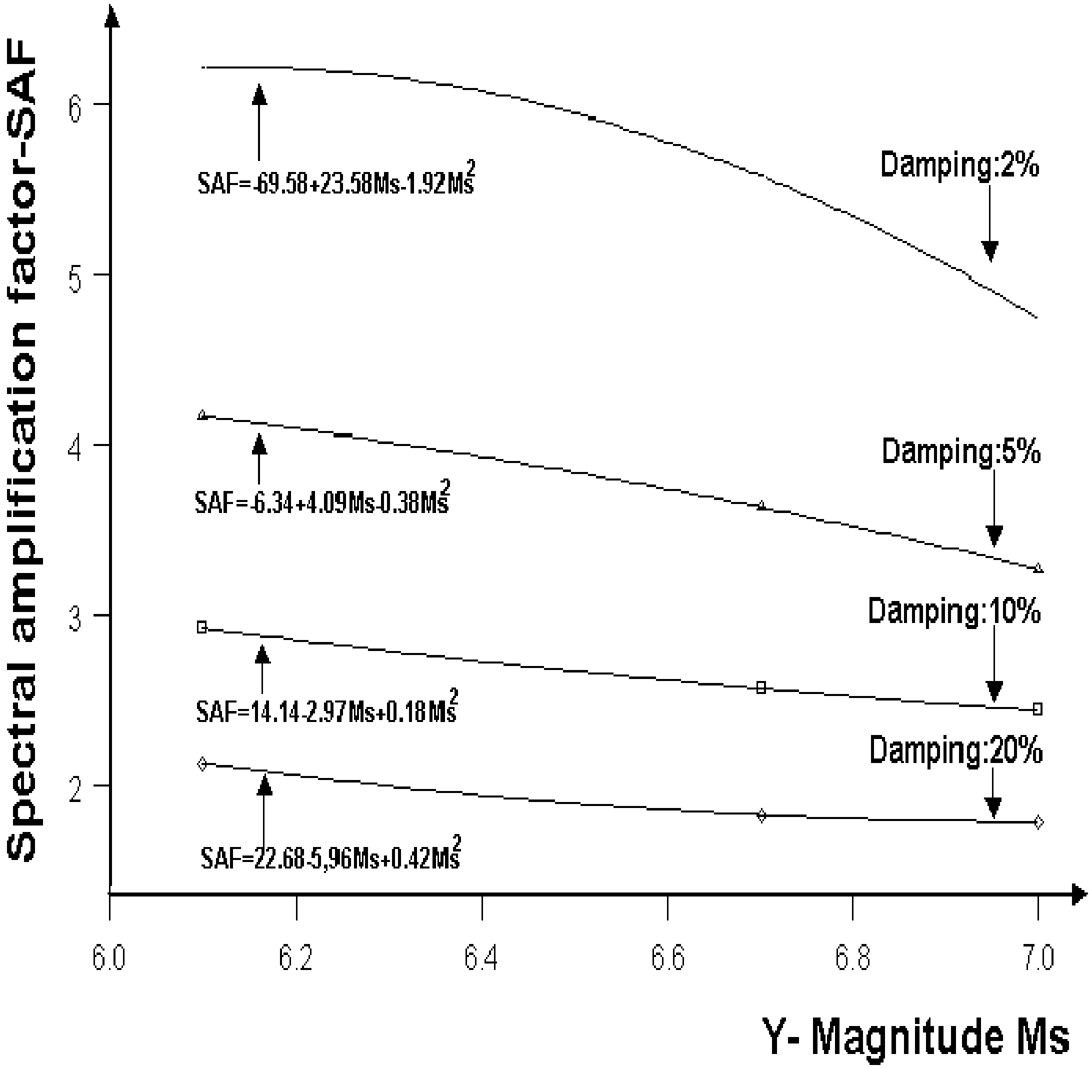
G_k for ω :

k	10 Hz	50 Hz	100 Hz
0	1365.813	1365.820	1365.821
1	6218.118	6218.143	6218.144
2	13607.324	13607.454	13607.458

D_k for ω :

k	10 Hz	50 Hz	100 Hz
0	$5.327\cdot10^{-2}$	$5.325\cdot10^{-2}$	$5.324\cdot10^{-2}$
1	$5.142\cdot10^{-3}$	$5.140\cdot10^{-3}$	$5.139\cdot10^{-3}$
2	$2.900\cdot10^{-5}$	$2.898\cdot10^{-5}$	$2.883\cdot10^{-5}$

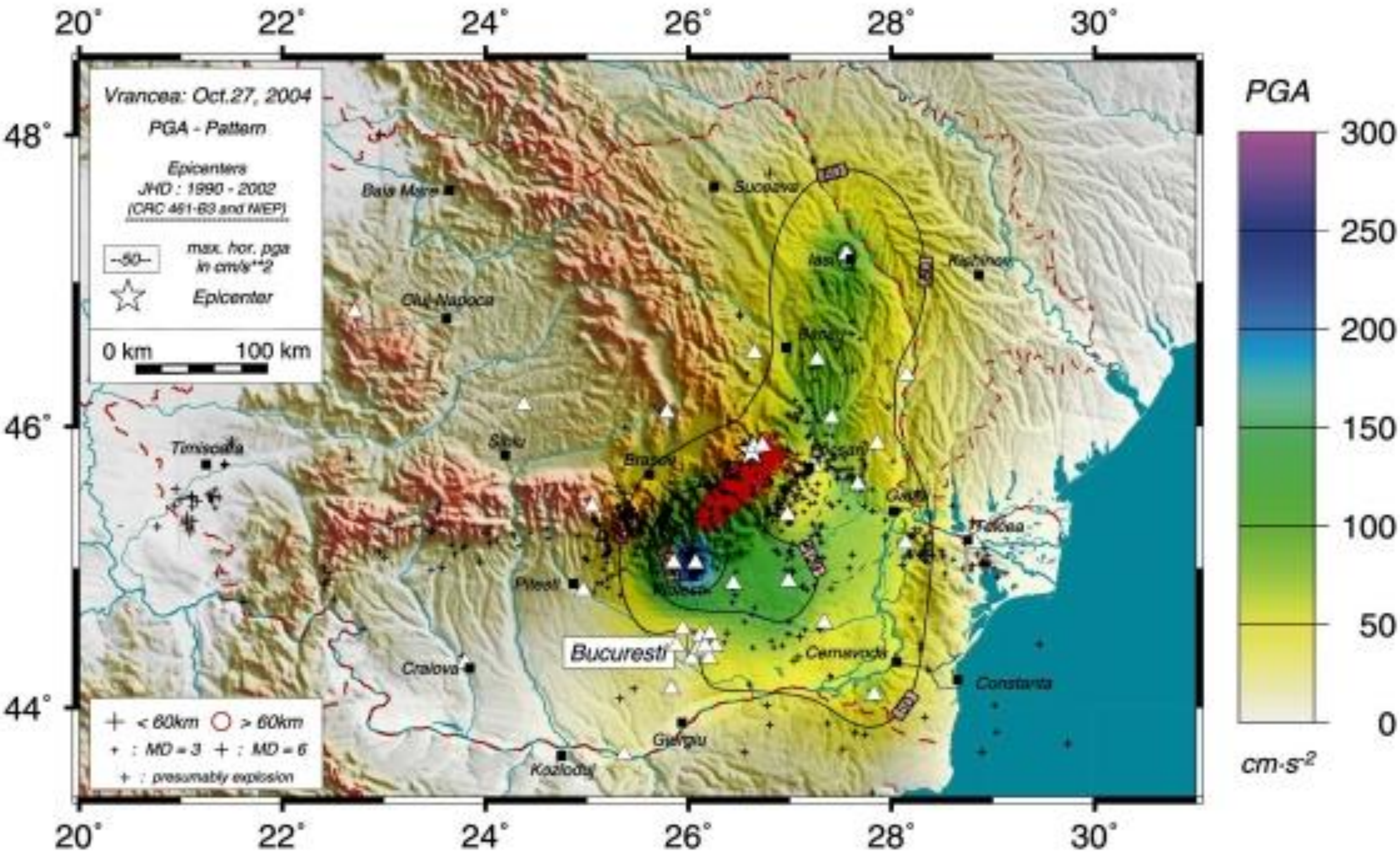
The variation of *dynamic torsion modulus function (G, daN/cm2*) and *torsion damping function (G%)* of specific strain(γ%) for *marl samples obtained in Hardin & Drnevich resonant columns (USA patent) from* NIEP, Lab.of Earthquake Engrg.



On the other hand, from Tables 1-19 and Figure 4 we can see that there is a strong *nonlinear* depen-dence of the spectral amplification factors(SAF) on earthquake magnitude for other seismic stations on Romanian territory on extra-Carpathian area (Iasi, Bacau, Focsani, Bucharest-NIEP, NPP Cernavoda, Bucharest-INCERC etc.).

SAF=3.13

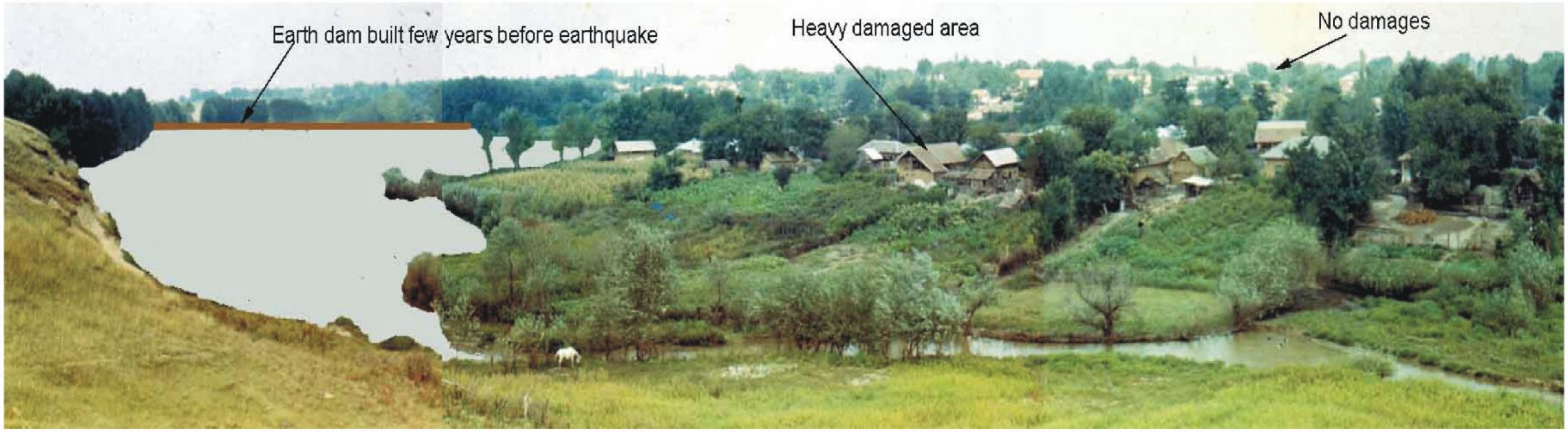
(Regulatory Guide 1.60 of the US Atomic Commission) & IAEA



Shake map **for last Romanian significant earthquake (Vrancea; October 27,2004, time: 20:34:30 PST; depth:100 km; magnitude: Mw =6.0). The epicenter of the earthquake is marked by a white star. The earthquake was felt within 200 km distance from the epicenter. It caused no serious injuries for people.**

The Romanian intermediate-depth earthquake of March 4, 1977

Place: Damian



(a)

(a)

Figure 5. *Sadova village situation: during (a) and after earthquake (b)*

Place:
Giurgiu

Figure 6. *Hole occurred in the Danube meadow as a result of liquefaction of sand deposits*

Areas with landslides, rocks faults and liquefactions during of March 4, 1977 Vrancea earthquake(M_W=7.5)

FOCUS ON REDUCING RISK, EARLY ACTIONS AND INCREASE COMMUNITY RESILIENCE

- **Accountability, participation, predictability and transparency are identified as the key features of an effective governance structure that does foster development and support risk reduction. On the other hand ,though, they are of direct relevance in the process of risk reduction because they facilitate the diversification of livelihood and enable the application of market-based instruments as incentives for physical mitigation measures, all of which reduces vulnerability.**
- **Natural disaster prevention, mitigation and response are not primarily technological or logical issues. The success of prevention and mitigation strategies depends on the degree of organization, understanding of the problem, and the acceptance by the population.**
- **Rapid urbanization increases the risk of urban public security, that are:**
  - **(i) -natural disaster from earthquakes, tsunami, earth slides, floods etc.,**
  - **(ii) -industrial accidents,**
  - **(iii)-public health and,**
  - **(iv)-social security.**

A.MITIGATING EARTHQUAKE RISK

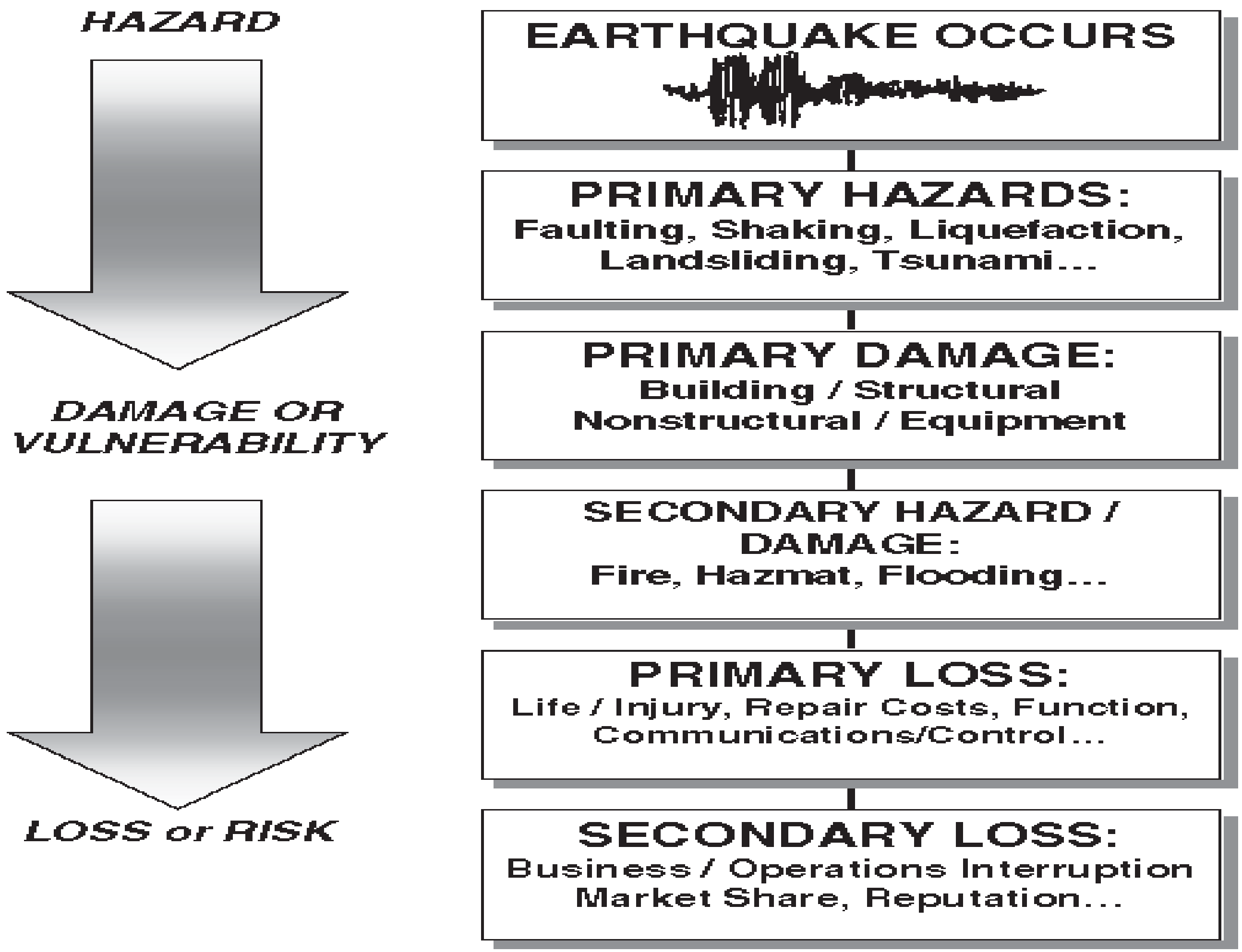


Figure 1.Earthquake loss process.

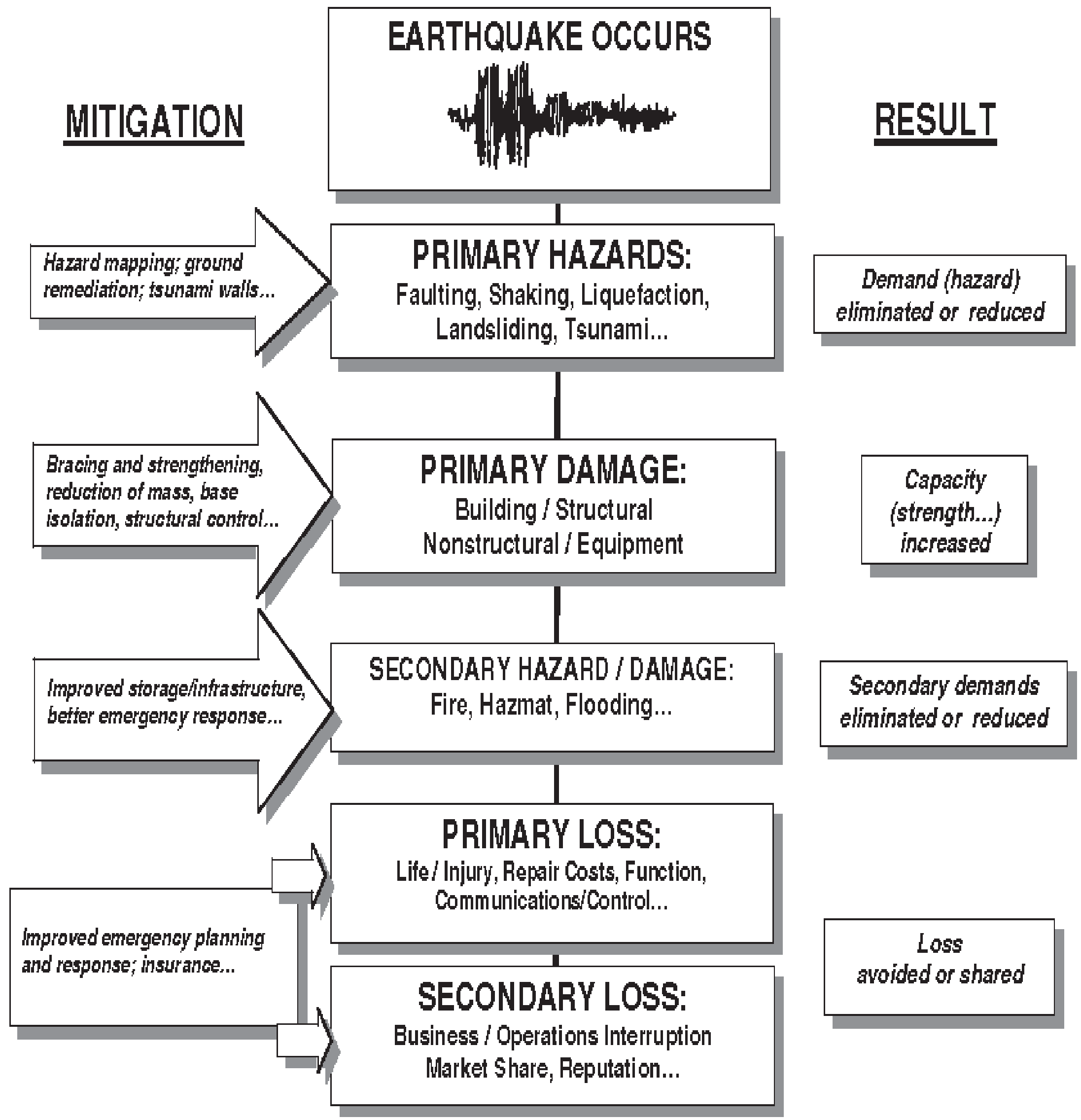


Figure 2. Mitigation of earthquake damage

B.EARTHQUAKE RISK MANAGEMENT DECISION-MAKING

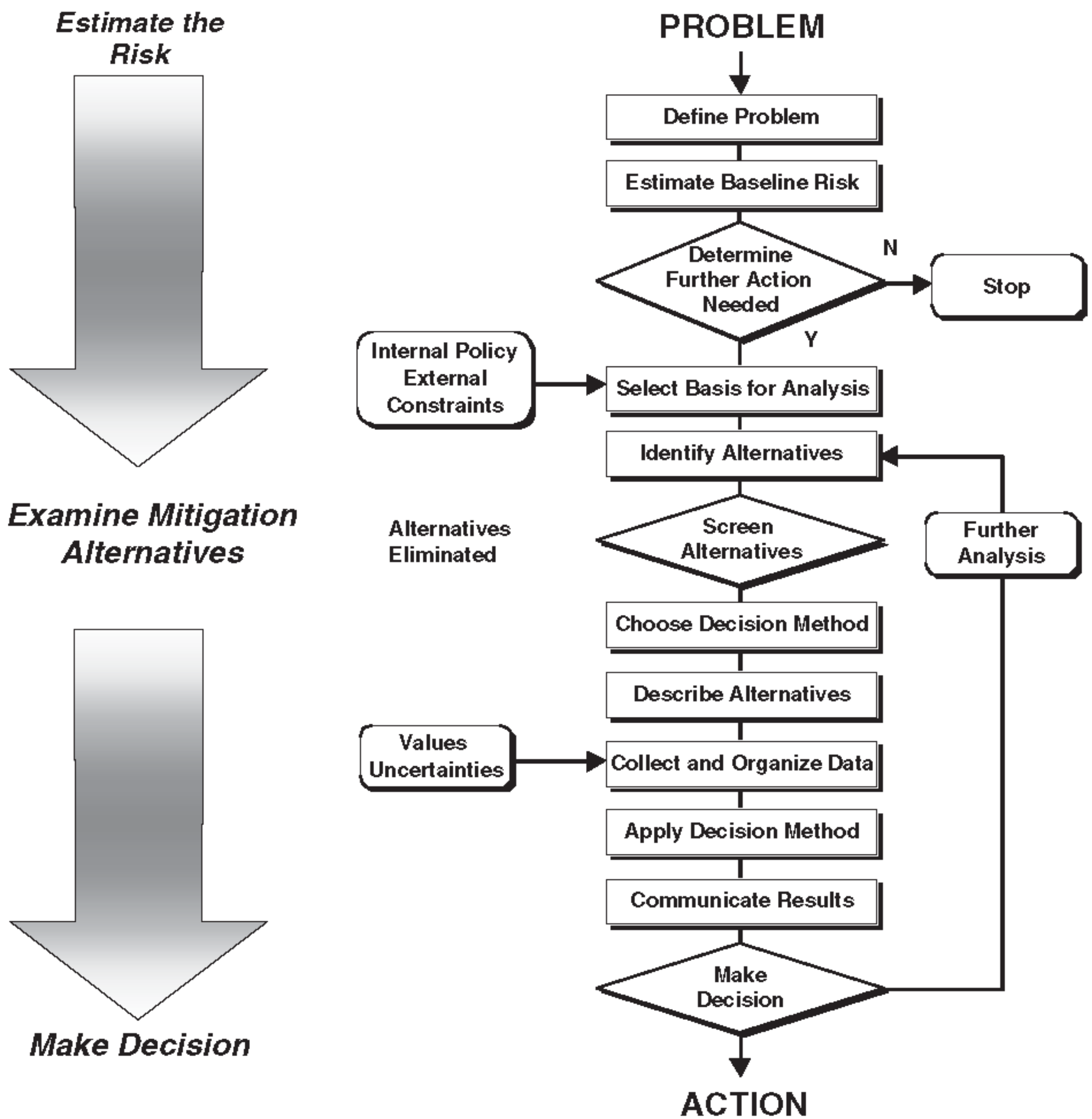


Figure 3.Earthquake risk management decision process

C. Earthquake Risk Management Program

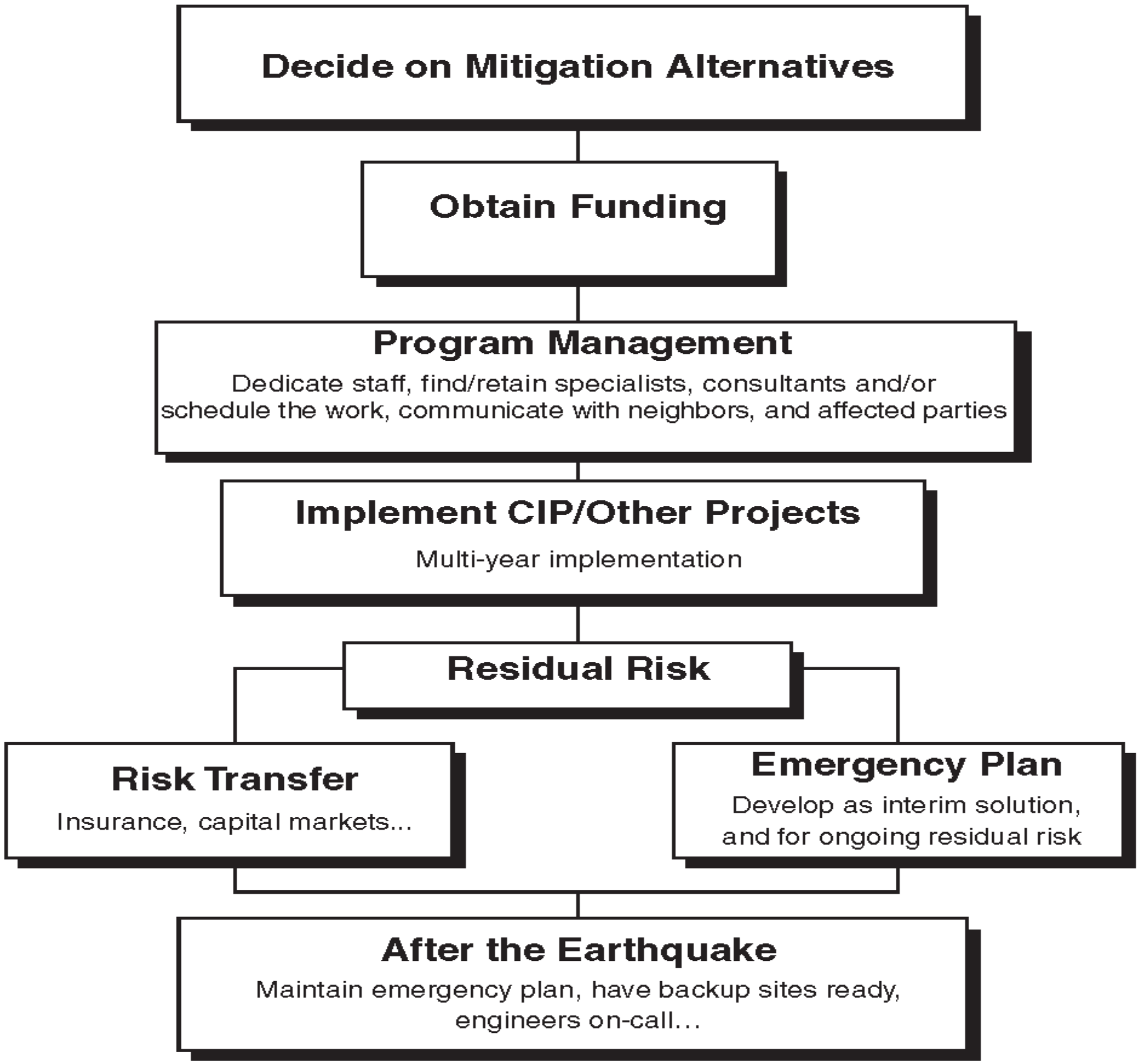


Figure 4 .Earthquake risk mitigation program

D. Summary

In summary, earthquake risk management consists of a series of rational steps aimed at:

1. **Identifying what is at risk - that is, what assets could be lost due to an earthquake;**
2. **Assessing how the earthquake places these assets at risk;**
3. **Determining which alternatives might reduce this risk;**
4. **Deciding among these alternatives, which are the best for the specific situation;**
5. **Implementing- that is, putting these alternatives into practice.**

Prof. Gh. Marmureanu
National Institute for Earth Physics, Bucharest

Thank you
for
your attention !