Regione Emilia-Romagna
Servizio Geologico, Sismico e dei Suoli

Università di Siena 1240

Regione Toscana

Verso una nuova mappa della pericolosità sismica

Dario Slejko

Caratteristiche e finalità della pericolosità sismica a scala nazionale e regionale

OGS

RISCHIO = PERICOLOSITÀ * VULNERABILITÀ * VALORE ESPOSTO

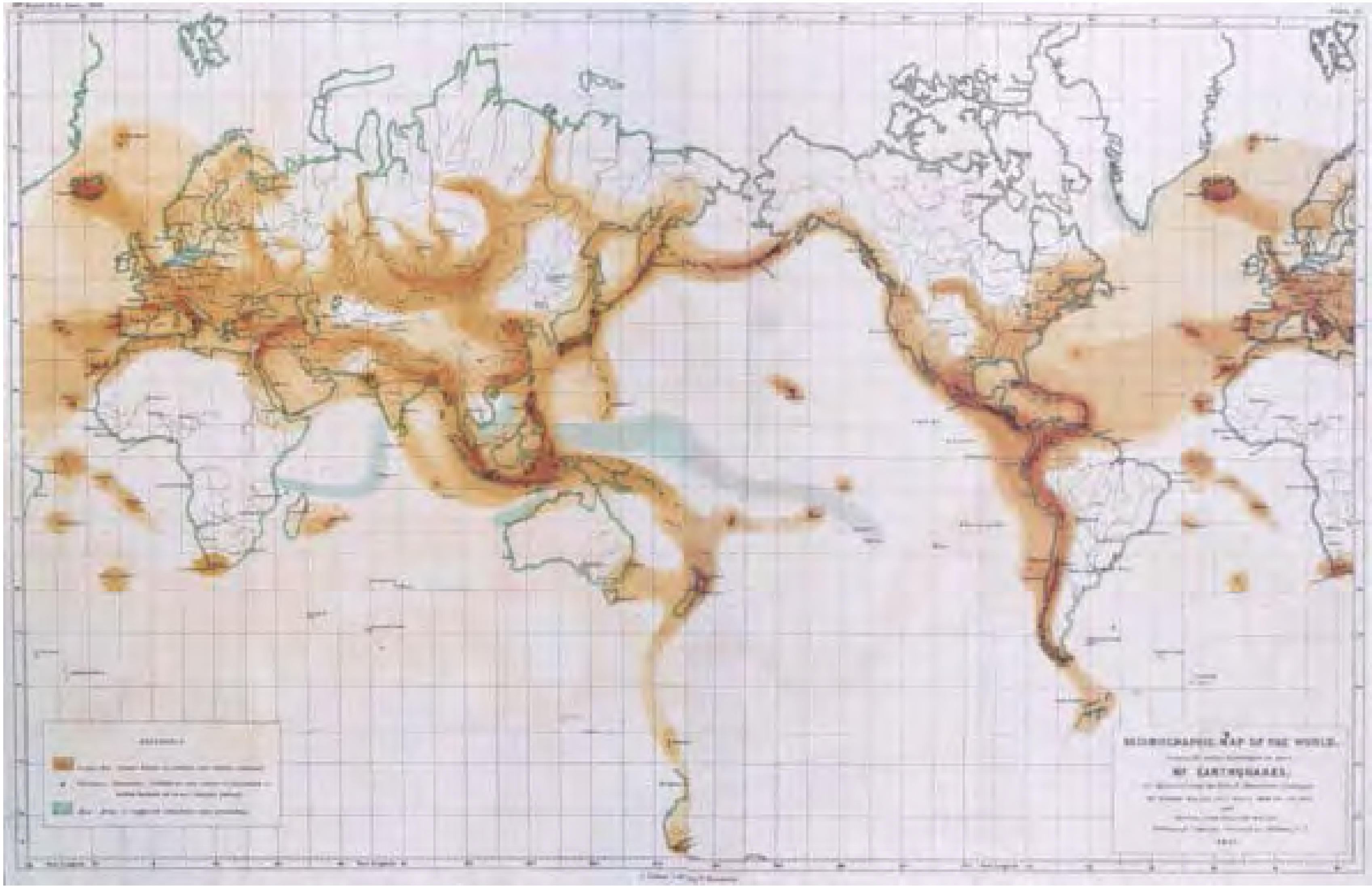
RISCHIO = probabilità di osservare un certo livello di danno o una certa perdita di funzionamento

PERICOLOSITA' = probabilità di osservare un certo scuotimento (accelerazione, intensità, ecc.) in un fissato periodo di tempo

VULNERABILITA' = propensione di un oggetto (edificio, sistema complesso, ecc.) a subire danni o alterazioni

VALORE ESPOSTO = quantificazione (economica, sociale, ecc.) dell'oggetto esposto a rischio

The first hazard map (?)



- Map of world earthquake occurrence by Robert Mallet in 1854

MODELLI DETERMINISTICI e STATISTICO-PROBABILISTICI

Determinismo = il processo E' NOTO e siamo capaci di scrivere l'equazione (modello)
Es.: caduta dei gravi $s = 1/2\ g*t^2$

Probabilismo = il processo NON E' NOTO e possiamo solo approssimarlo dalle osservazioni
Es.: exit poll

MODELLI DETERMINISTICI

CALCOLO DELLA PERICOLOSITA’ SISMICA

Metodi probabilistici

- Determinismo storico
- Probabilismo storico
- Probabilismo sismotettonico
- Probabilismo non poissoniano
- Previsione sismica

Metodi deterministici

- Moto di riferimento
- Scenario dettagliato

Muir Wood, 1993

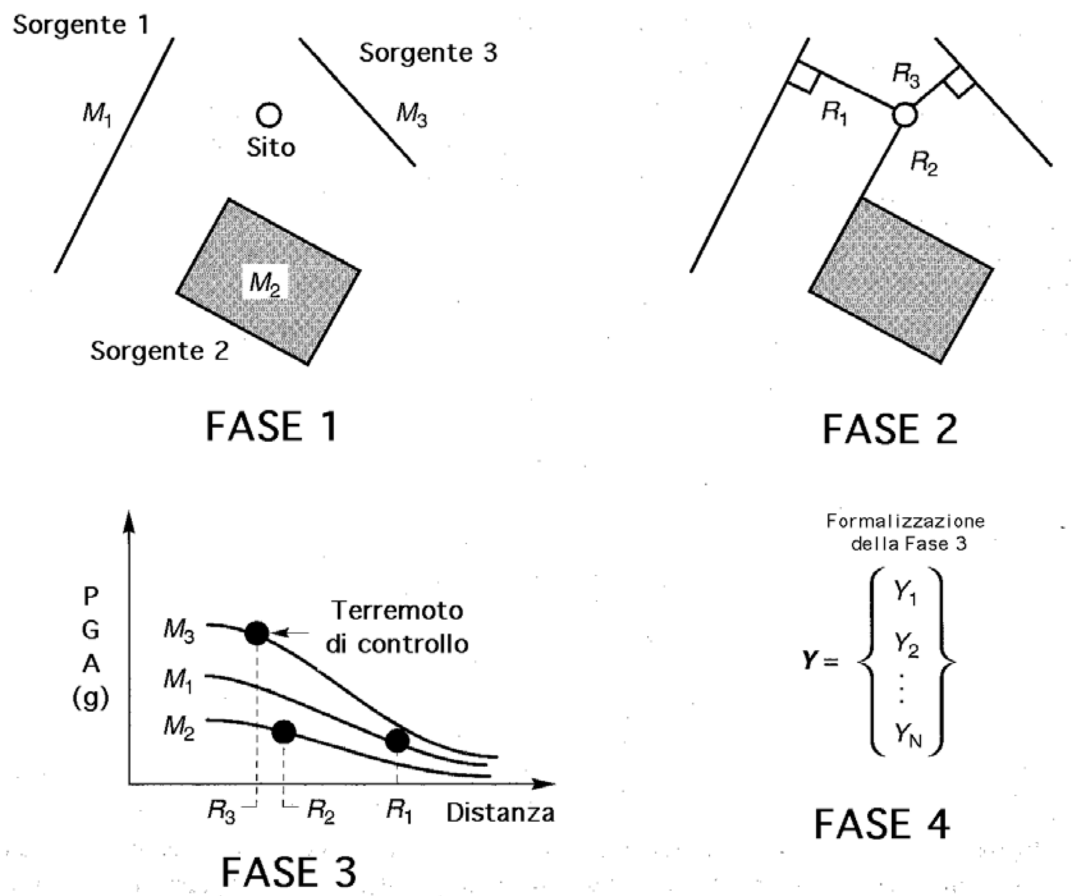
SCHEMA DELL'APPROCCIO DETERMINISTICO

1. Identification and characterization of all earthquake sources capable of producing significant ground motion at the site.

2. Selection of a source-to-site distance parameter for each source zone. In most DSHAs, the shortest distance between the source zone and the site of interest is selected.

3. Selection of the controlling earthquake (i.e., the earthquake that is expected to produce the strongest level of shaking), generally expressed in terms of some ground motion parameter, at the site.

4. The hazard at the site is formally defined, usually in terms of the ground motions produced at the site by the controlling earthquake. Its characteristics are usually described by one or more ground motion parameters obtained from predictive relationships.



L’APPROCCIO STATISTICO-PROBABILISTICO

• Permette di definire un livello di rischio “accettabile” (p.es. 10% in 50 anni) confrontabile con altri rischi naturali ed artificiali: SCELTA POLITICA

• Viene applicato sia per la normativa sismica (edilizia residenziale) che per le strutture speciali (gasdotti, centrali nucleari, ecc.)

• Viene scelto abitualmente un modello indipendente dal tempo per l’accadimento dei terremoti perchè:

- mancano i dati per modelli più sofisticati
- le norme non possono essere modificate dopo ogni terremoto

APPROCCI PROBABILISTICI

SEISMIC HAZARD ASSESSMENT

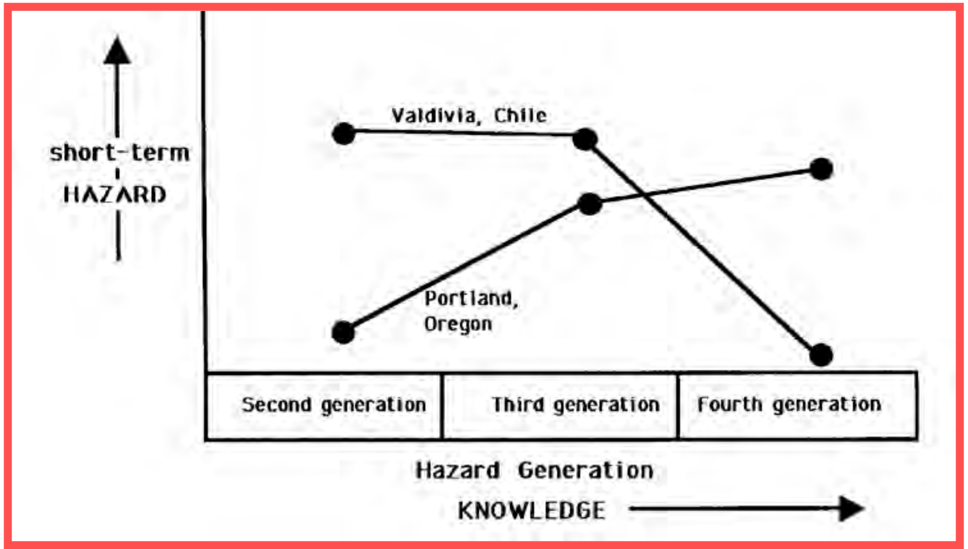
Probabilistic Approaches

- Historical Determinism
- Historical Probabilism
- Seismotectonic Probabilism
- Non-Poissonian Probabilism
- Earthquake Prediction

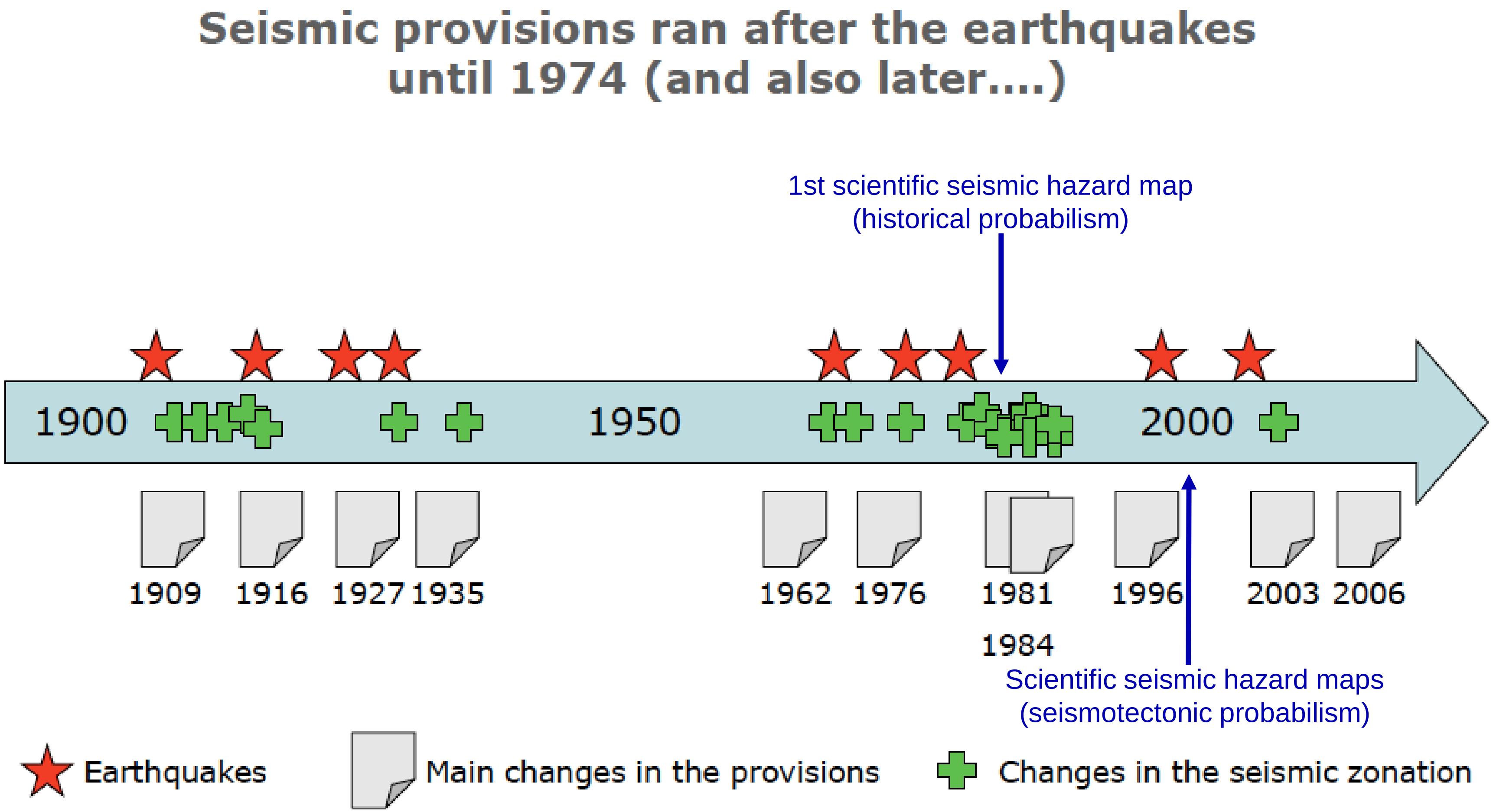
Deterministic Approaches

- Reference Shaking
- Detailed Scenario

(Muir-Wood, 1993)

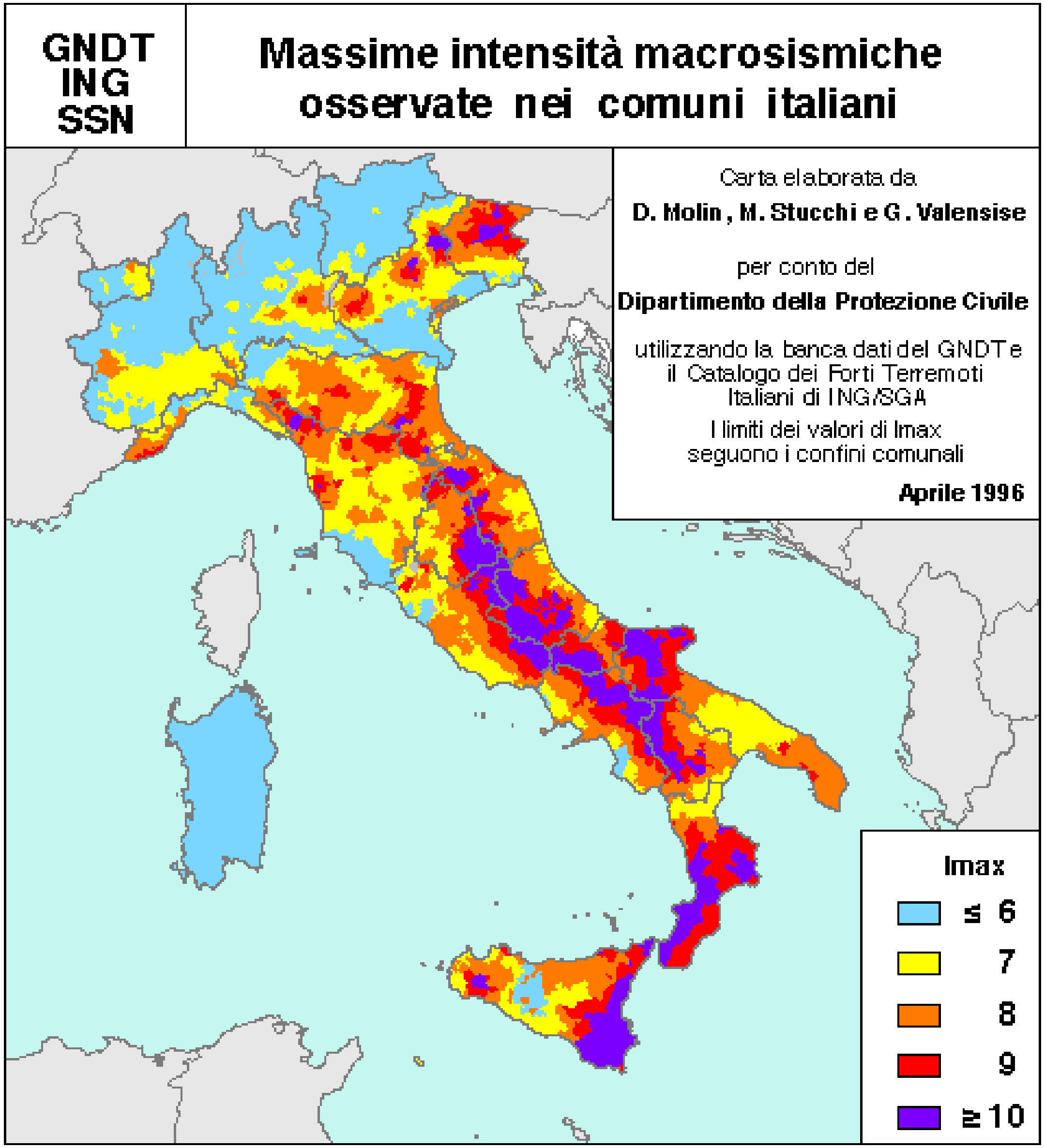


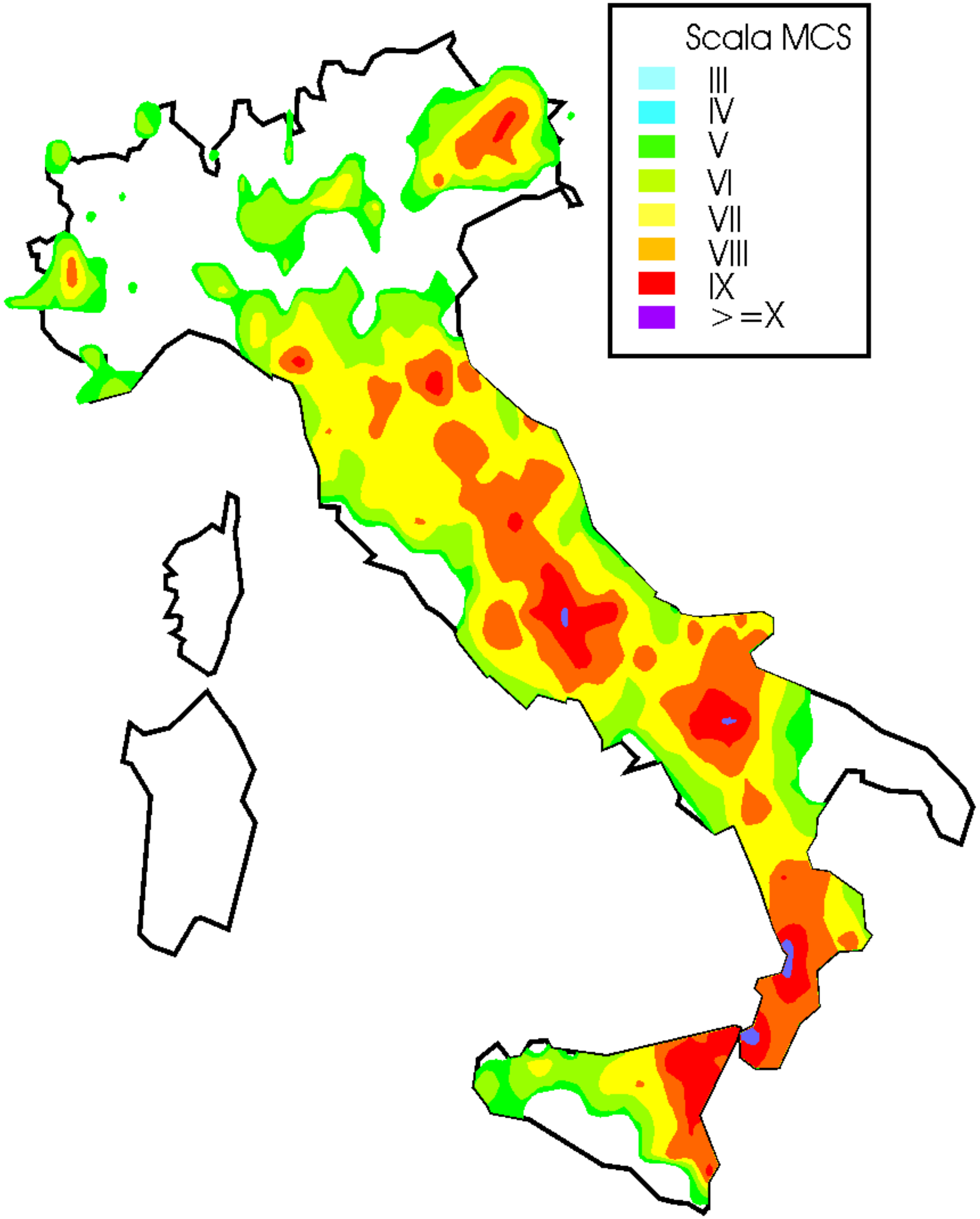
La zonazione sismica italiana



Meletti e Stucchi (2011)

La pericolosità “non scientifica” pre-1980



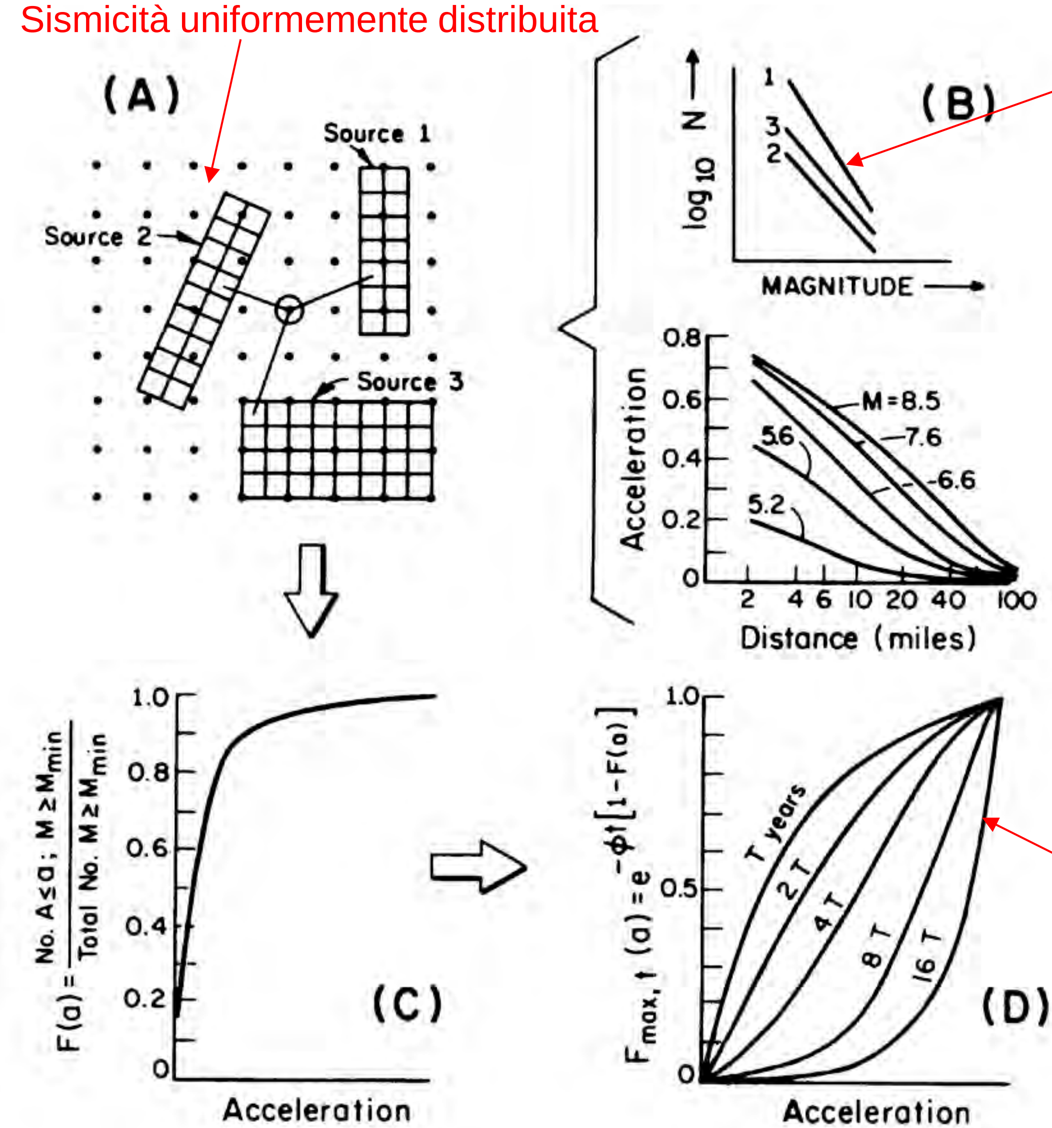


La prima pericolosità "scientifica", base della zonazione sismica italiana 1980

Carta di pericolosità del "Progetto Finalizzato Geodinamica" del CNR preparata nel 1979
e servita come base
per la classificazione sismica nazionale 1980 - 1984.

Il calcolo era di tipo statistico sulla base dei dati del catalogo dei terremoti.

Il metodo del Probabilismo Sismotettonico

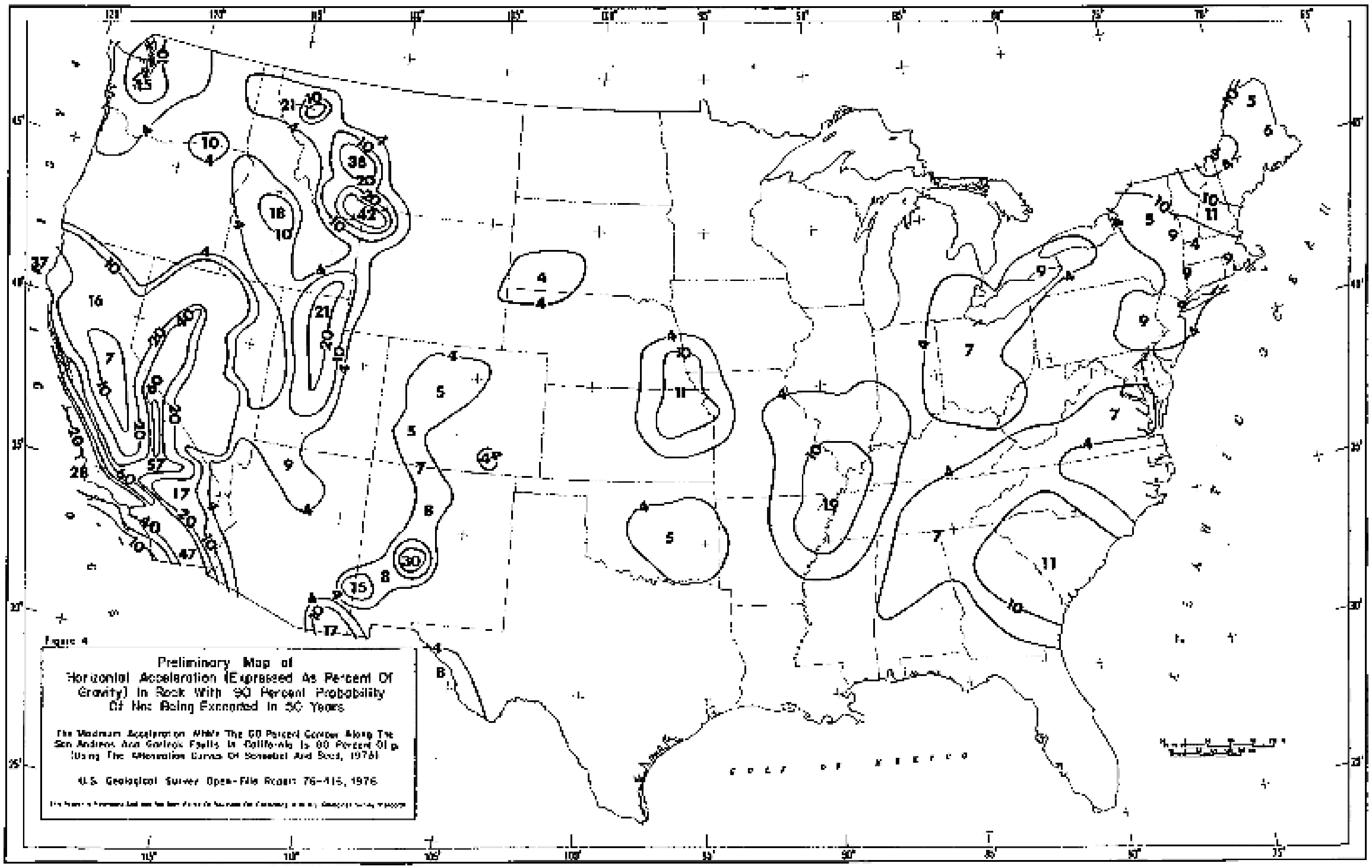


Il metodo di Cornell (1968)

1) la magnitudo dei terremoti è distribuita esponenzialmente;
2) I tempi di intercorrenza fra gli eventi formano un processo poissoniano;
3) la sismicità è distribuita uniformemente all'interno delle sorgenti sismogenetiche (faglie, zone, ecc.).

(from Algermissen & Perkins 1976)

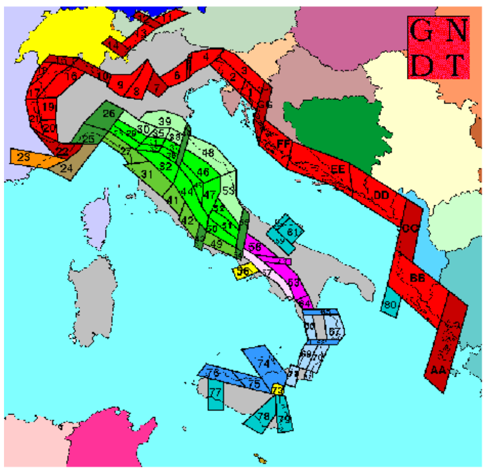
The first modern hazard map



USGS seismic hazard map of the US (Algermissen & Perkins, 1976)
based on the seismotectonic approach

Valutazione della pericolosita' sismica alla scala nazionale GNDT 1990-1995

Zonazione Sismotettonica

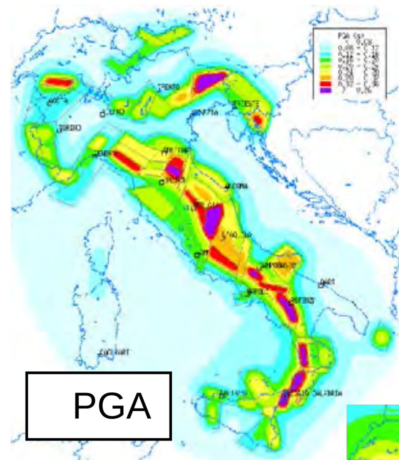


SORGENTI AREALI

Revisione Catalogo dei Terremoti

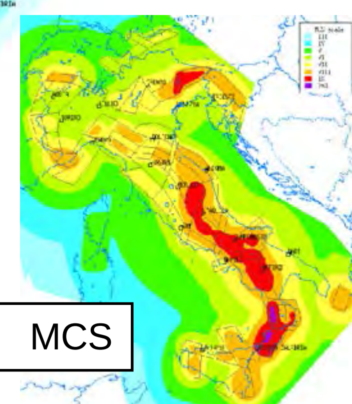
CATALOGO & DATABASE

Stima Probabilistica moto del suolo



PGA

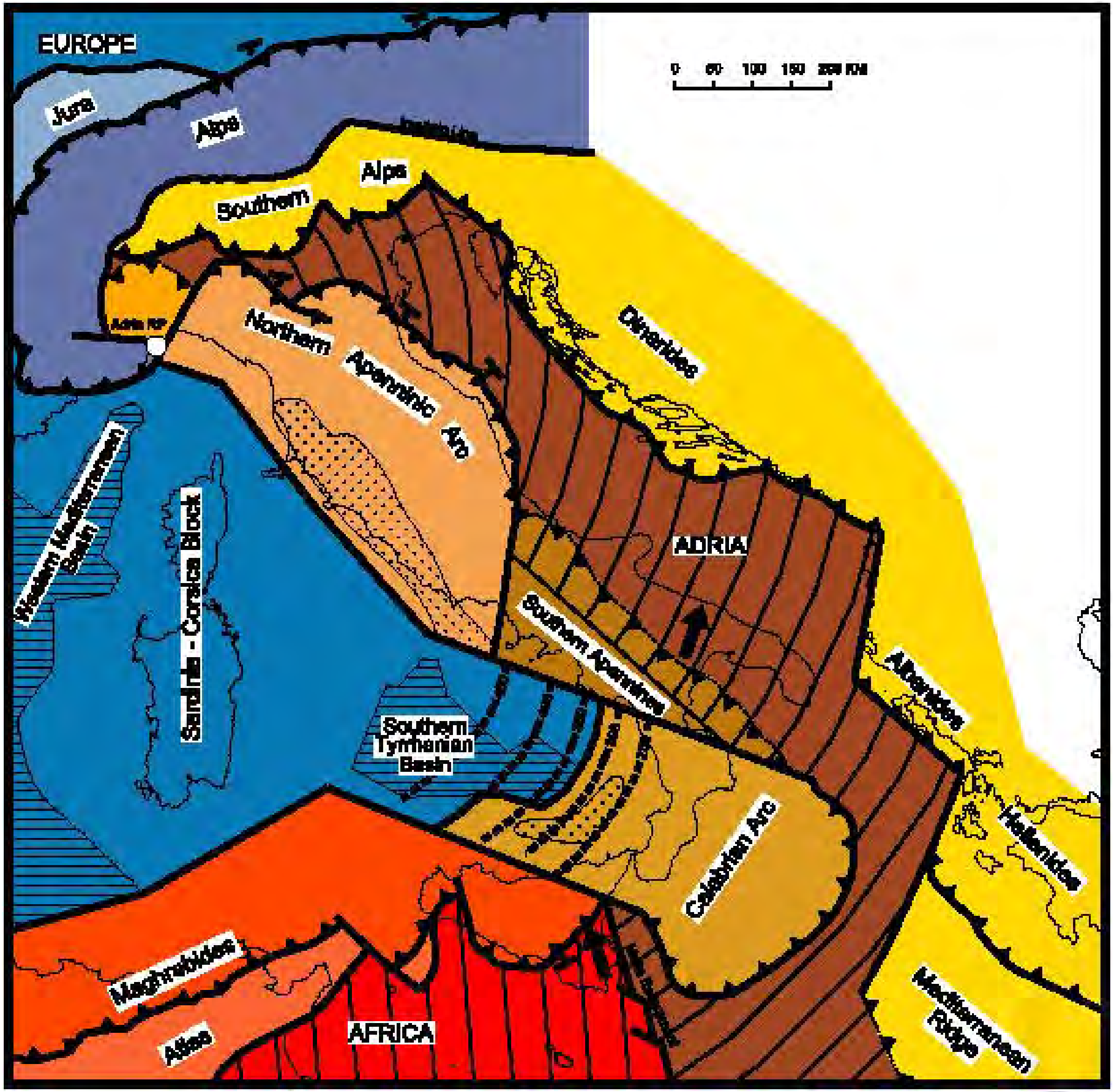
1996



MCS

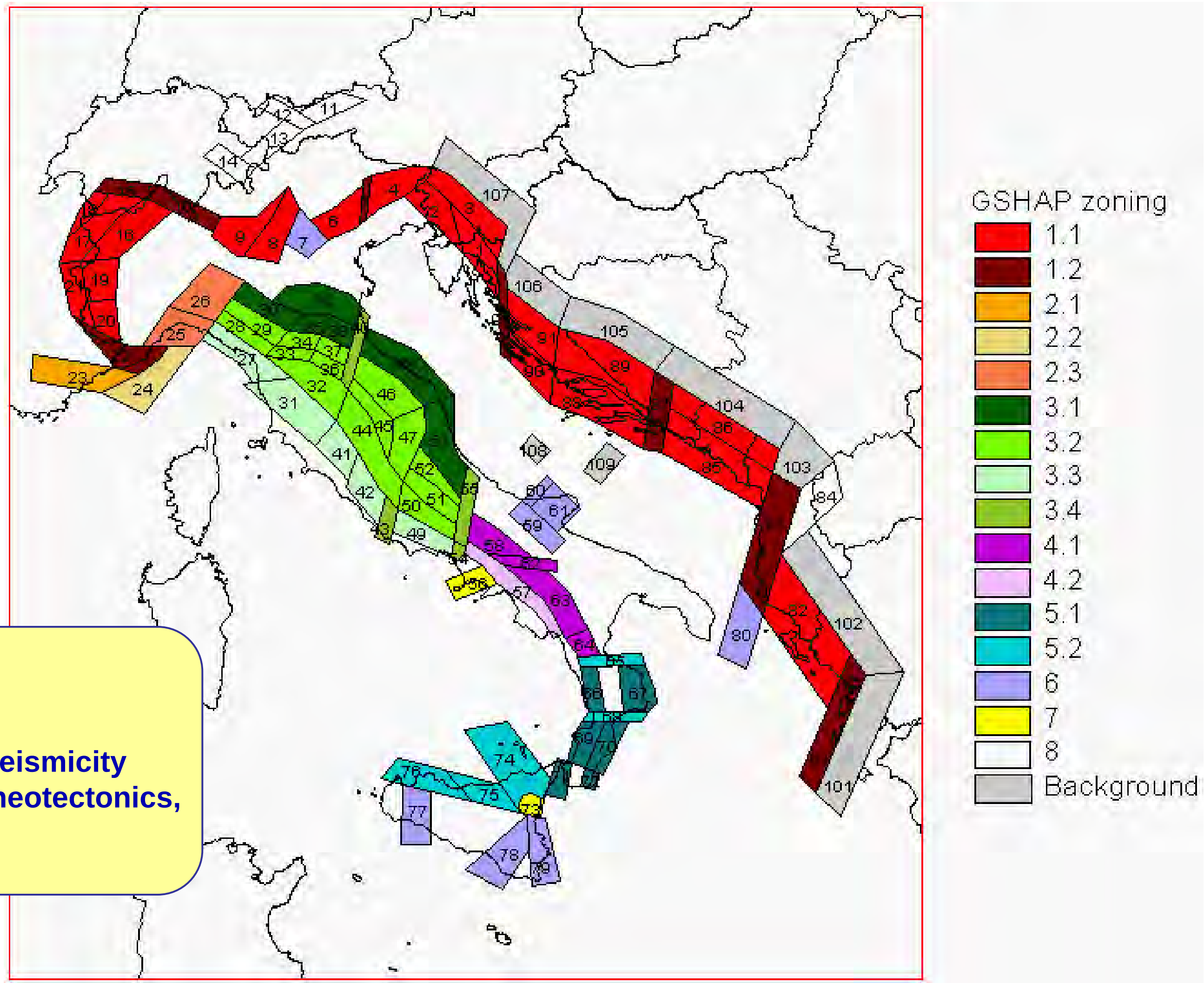
General framework: kinematic model of Adria

The SZs are drawn
on the basis
of the slip vector pattern
representing
the kinematic model
of the Adria microplate



Seismogenic zonation of Italy

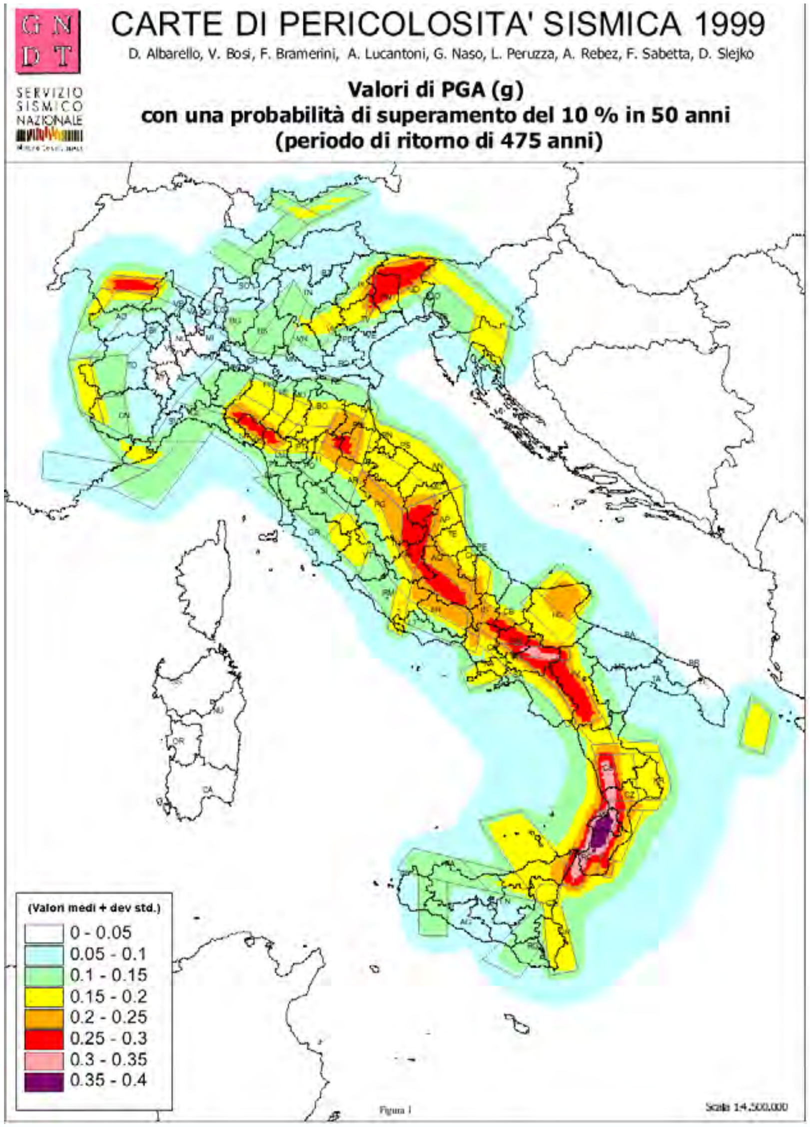
Legend:
1. Seismic source zones related to the interaction between Adria and Europe.
2. Alps/Apennine transfer zones.
3. Seismic source zones related to the sinking of the Adria lithosphere and to the uplift of the asthenosphere.
4. Seismic source zones related to the deactivation of the thrust belt - foredeep system and to the counterclockwise rotation of Adria.
5. Seismic source zones of the Calabrian Arc.
6. Seismic source zones inside the foreland region and along the flexural margins.
7. Seismic source zones in active volcanic regions.

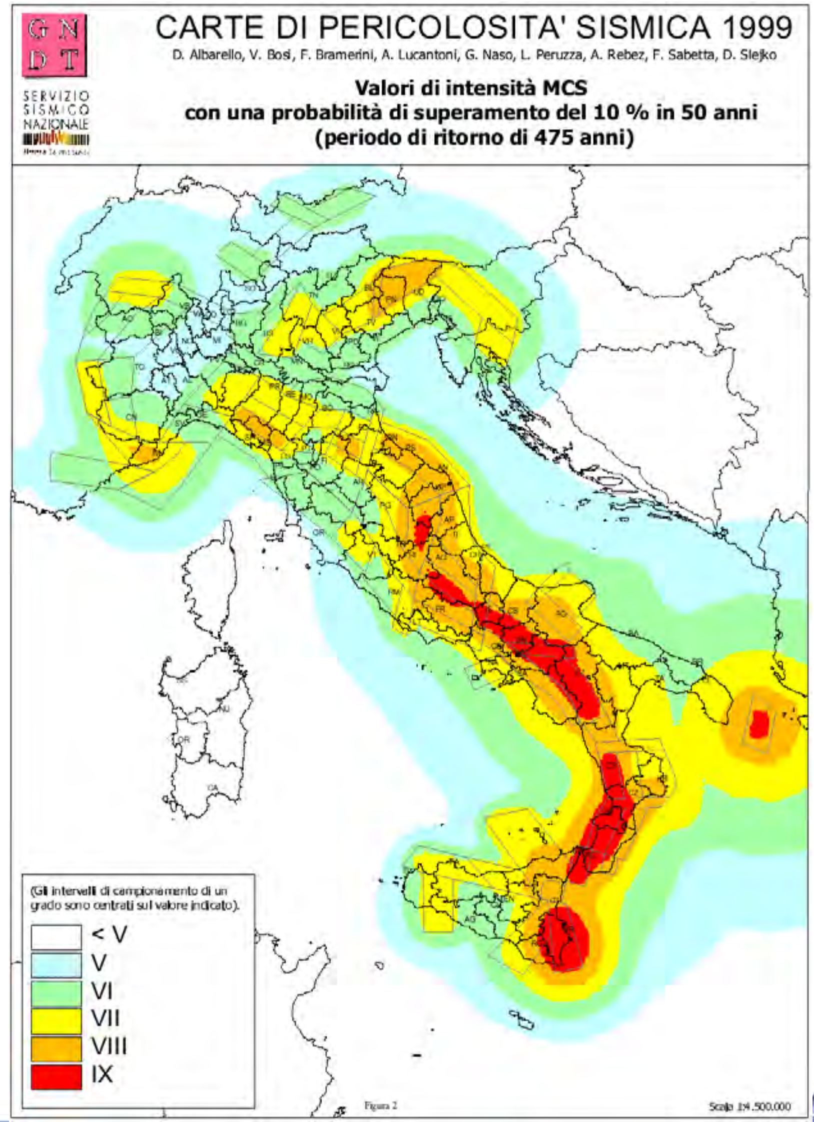


Identification: supported by geology, neotectonics, seismicity
Geometry: controlled by kinematics, seismicity
Behaviour: controlled by kinematics, neotectonics, intensity maps, fps

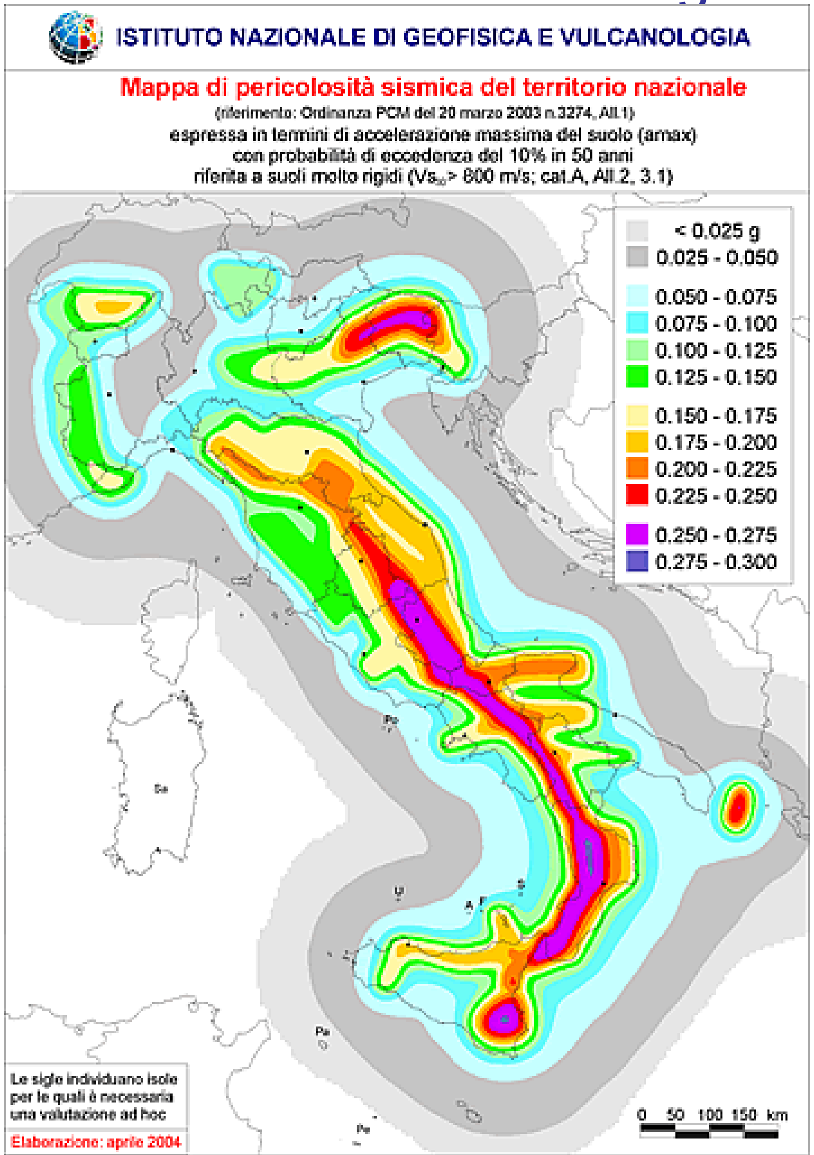
(from Slejko et al., 1999)

Le mappe “di consenso”: base della classificazione 2003

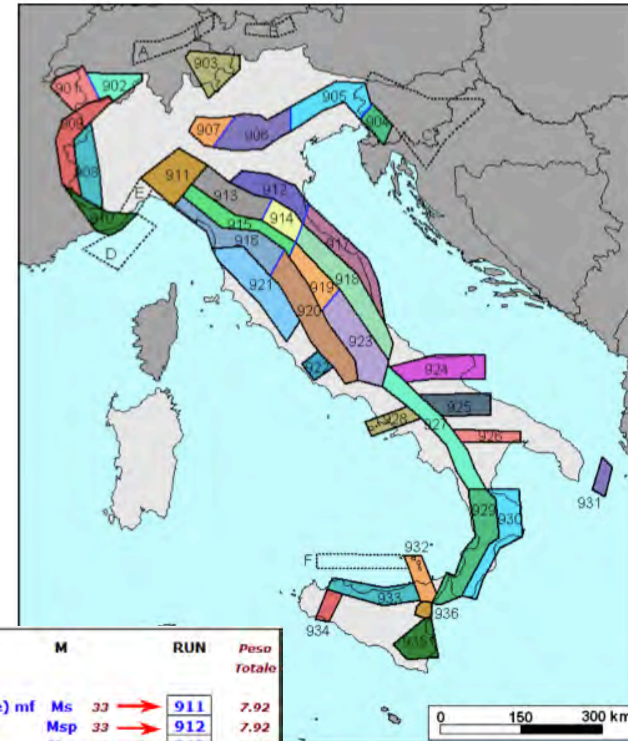


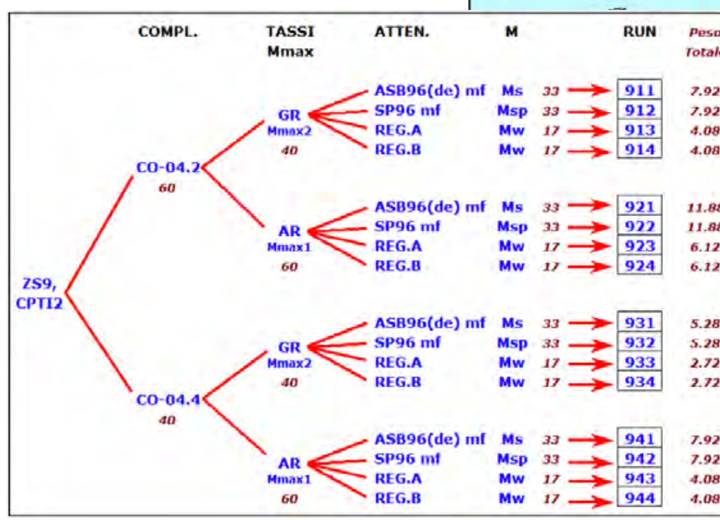


The most recent seismic hazard map of Italy in agreement with Ord. 3274



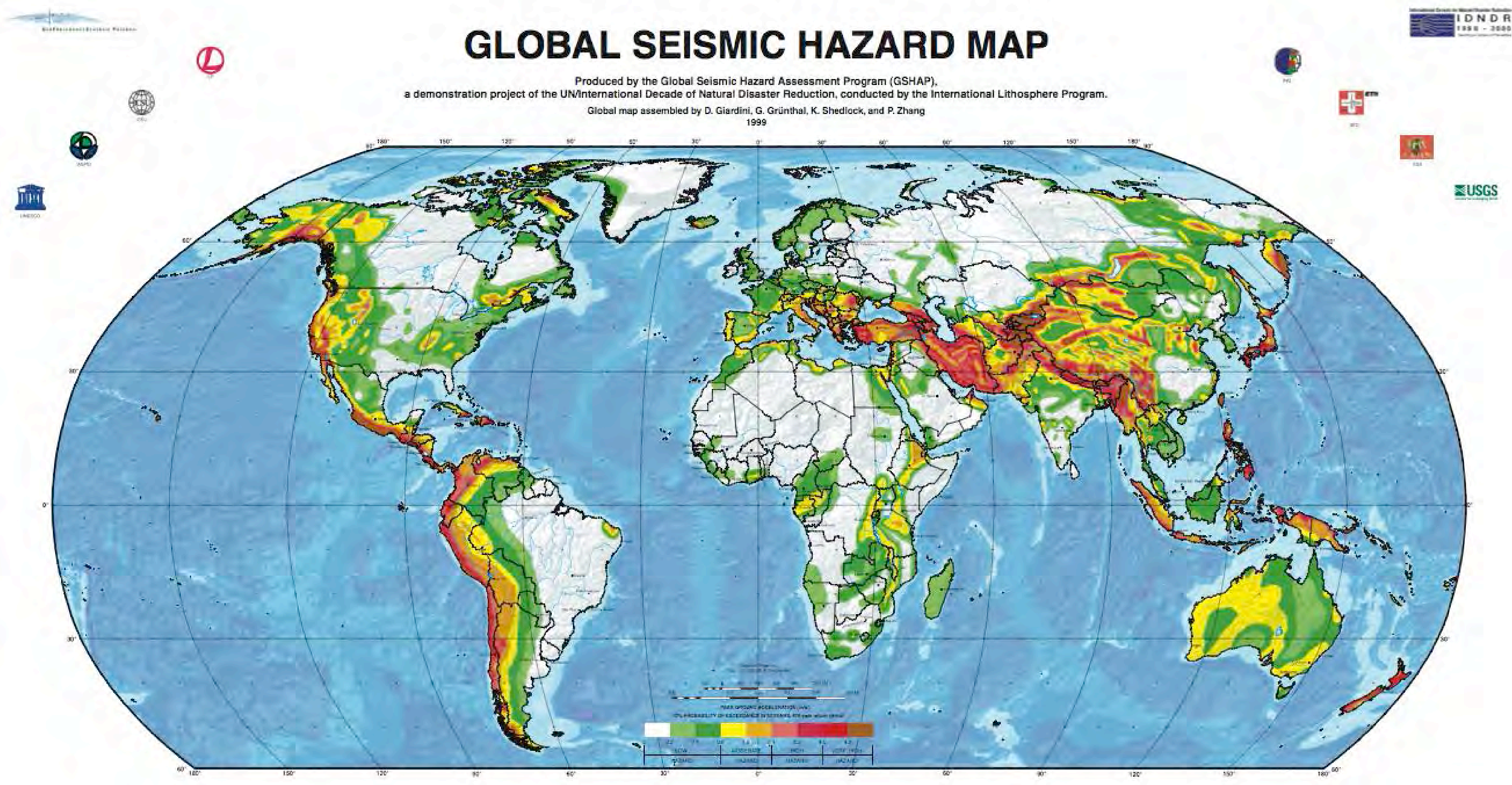
Seismic hazard map (Gruppo di Lavoro, 2004) used as basis of the present Italian seismic zonation





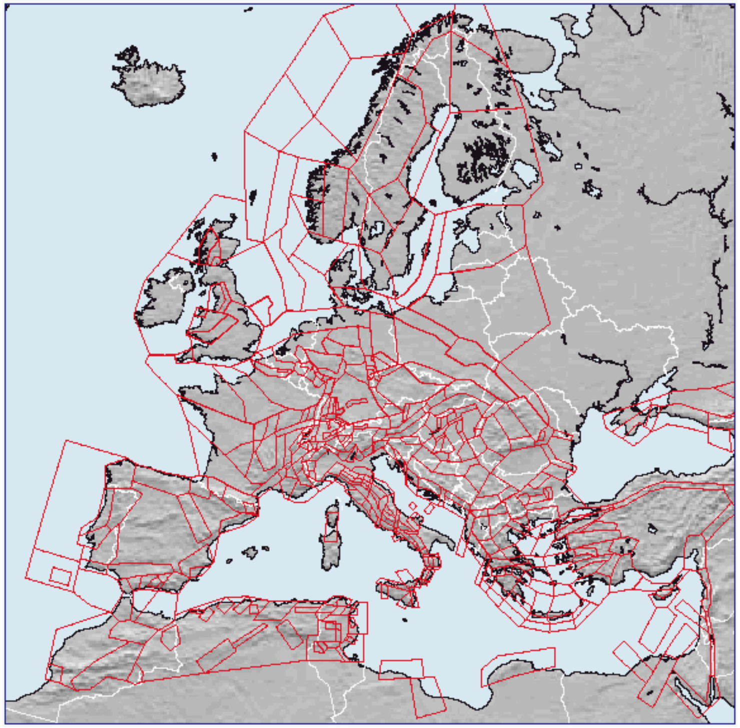
The GSHAP project

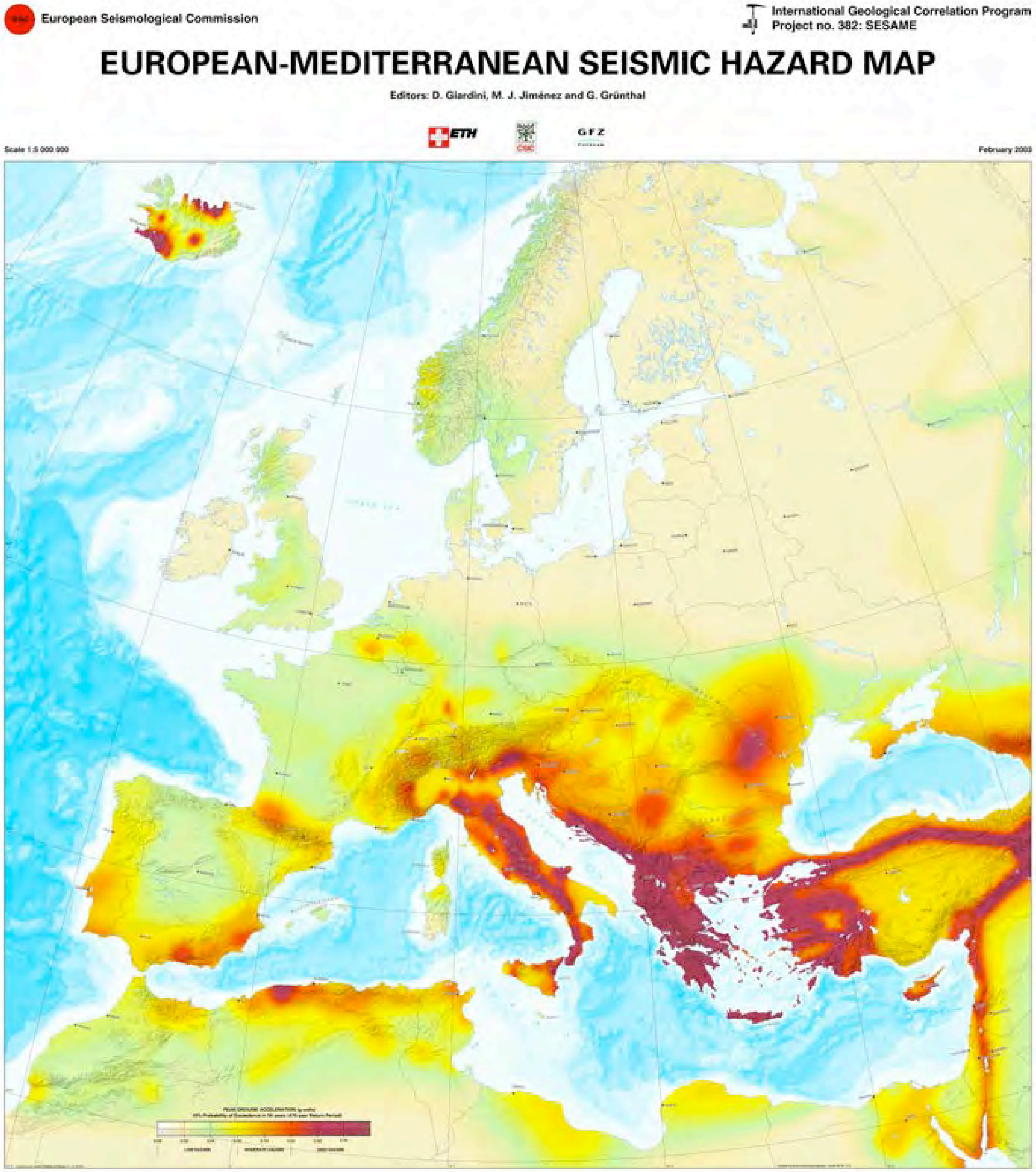
- Seismic hazard map produced by GSHAP (Giardini et al., 1999)
  http://www.seismo.ethz.ch/GSHAP/index.html

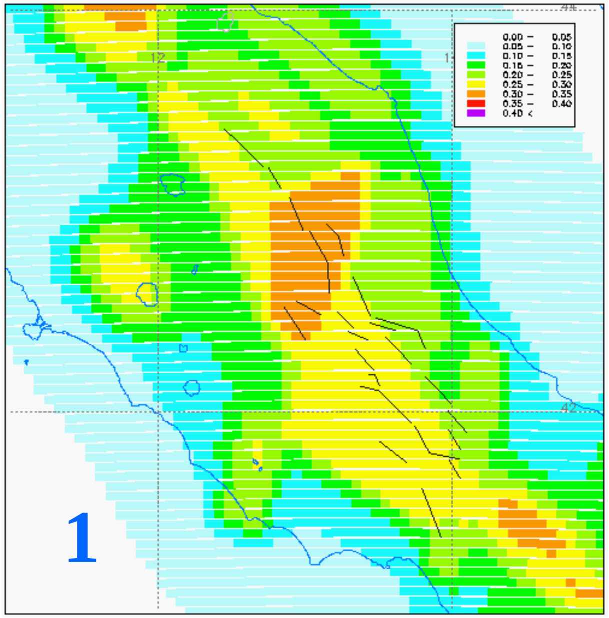


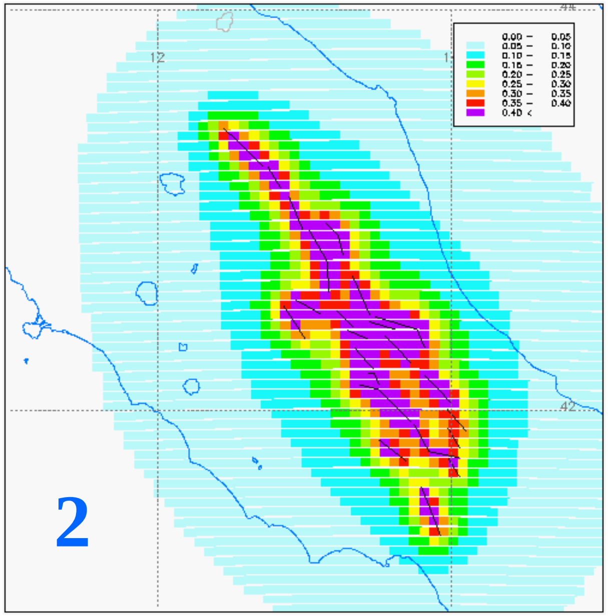
The ESC project

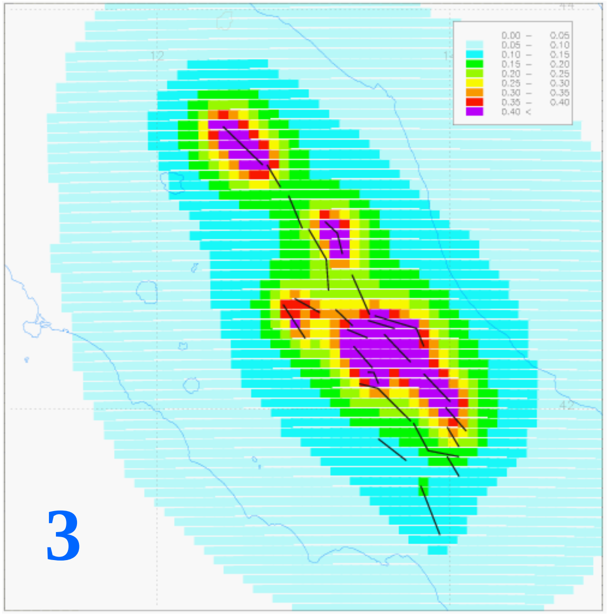
- Seismic hazard map of the European – Mediterranean region (Jimenez et al., 2003) http://wija.ija.csic.es/gt/earthquakes/











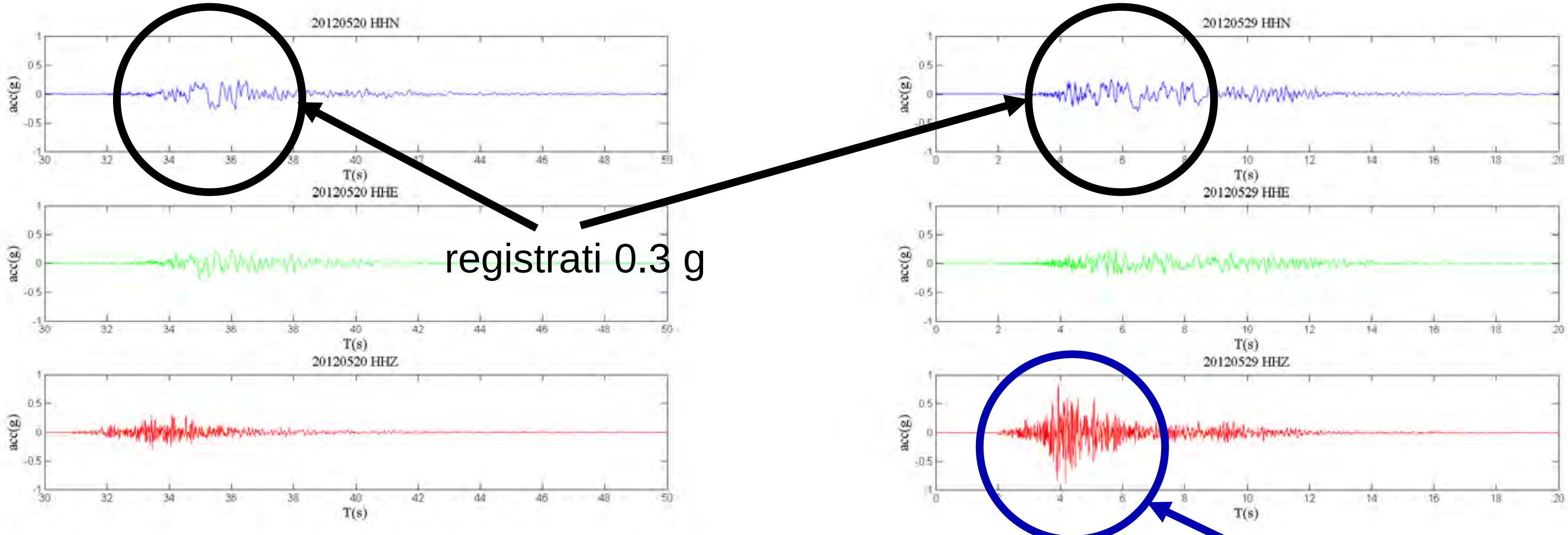
From the 3rd to the 4th generation PSHA

Seismic Hazard in Central Italy

475-yr return period PGA

1 - Cornell approach with SZ’s
2 - Cornell approach with faults
3 - characteristic time-dependent eq on faults

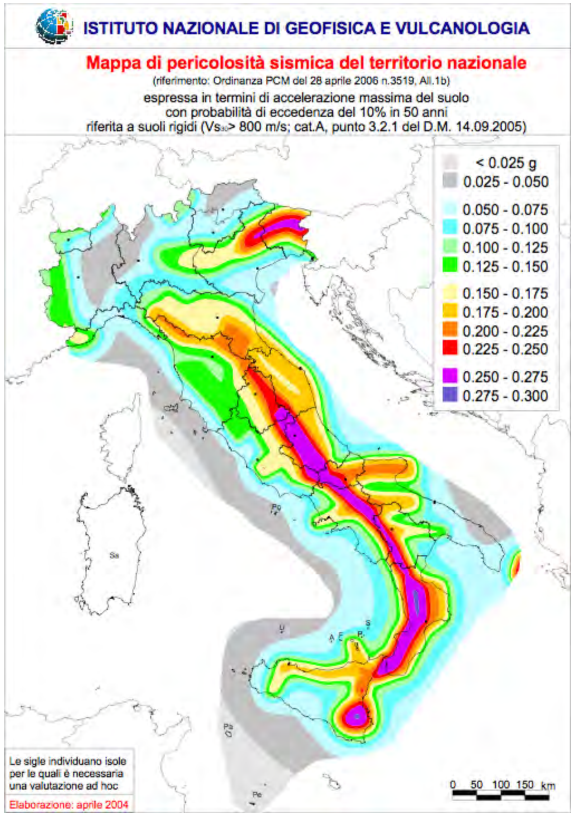
Un terremoto inatteso?

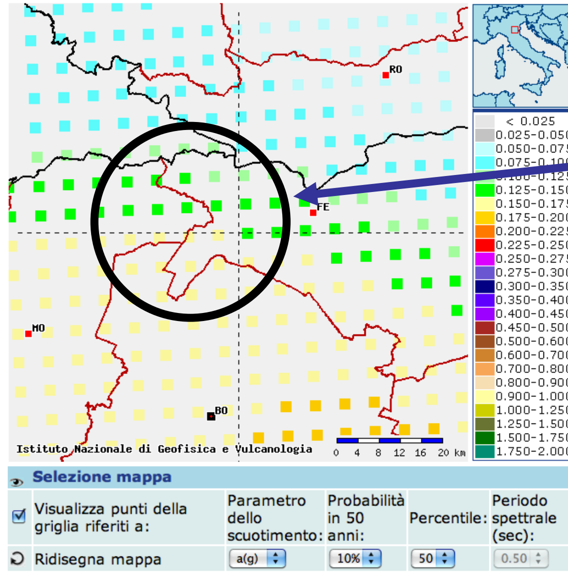


registrati 0,9 g

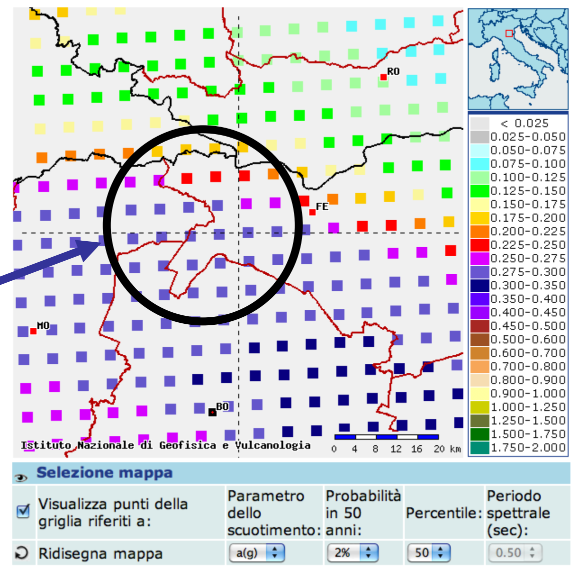
La forte accelerazione verticale della prima scossa ma molto di più della seconda ha provocato I danni intensi ai capannoni industriali, non progettati per resistere a sollecitazioni verticali forti.

La mappa di pericolosità sismica è sbagliata?

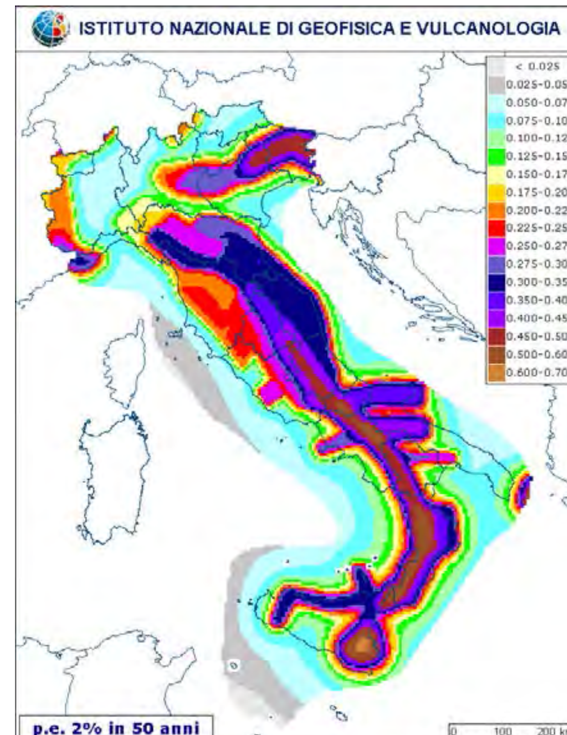




Siamo a 0.15 g
per pe=10% in 50 anni



Siamo a 0.3 g
per pe=2% in 50 anni



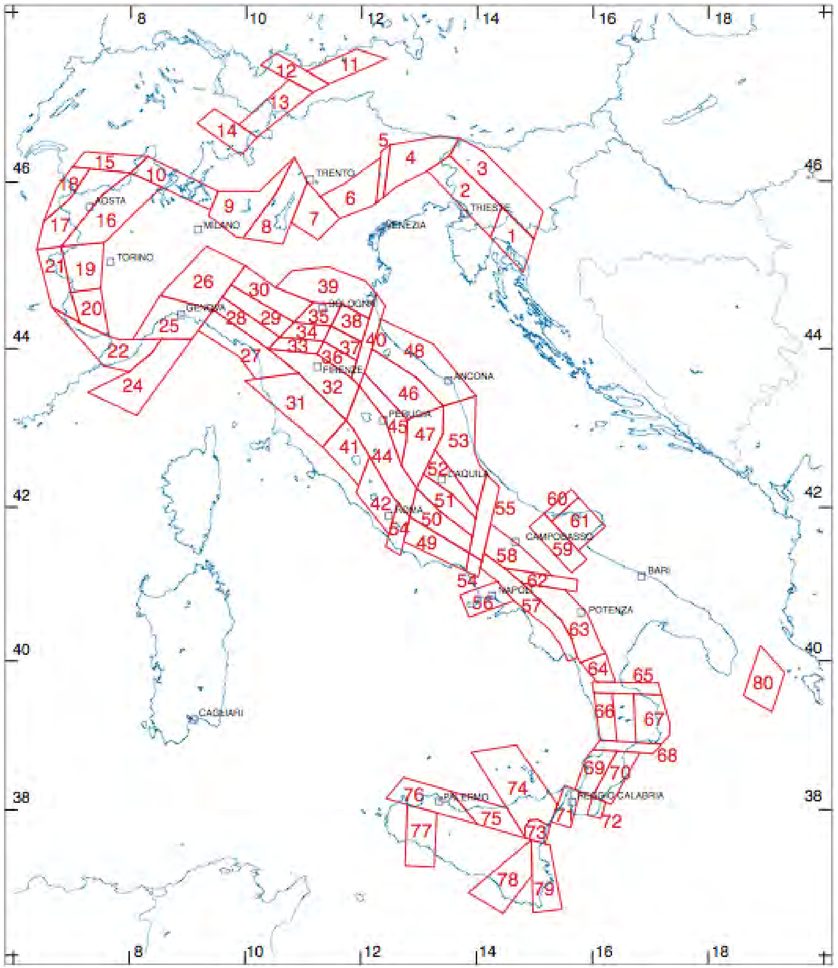
MODELLI SISMOGENETICI NAZIONALI e REGIONALI

- I modelli regionali utilizzano dati tettonici di dettaglio

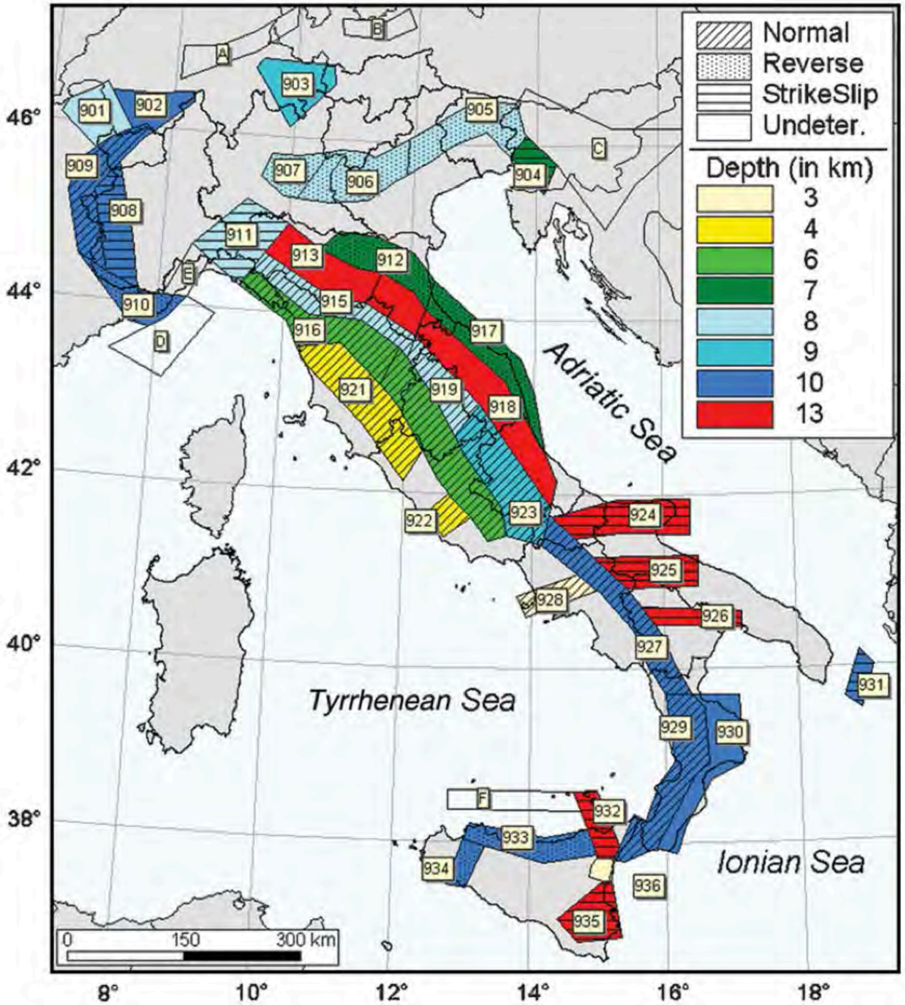
- I modelli regionali sono calibrati anche sulle caratteristiche della sismicità di basso livello (registrati da reti locali)

- Ne deriva che possono definire anche sorgenti di dimensioni spaziali limitate: queste differenze sono reali o sono speculazioni scientifiche?

Zonazioni sismogenetiche a confronto

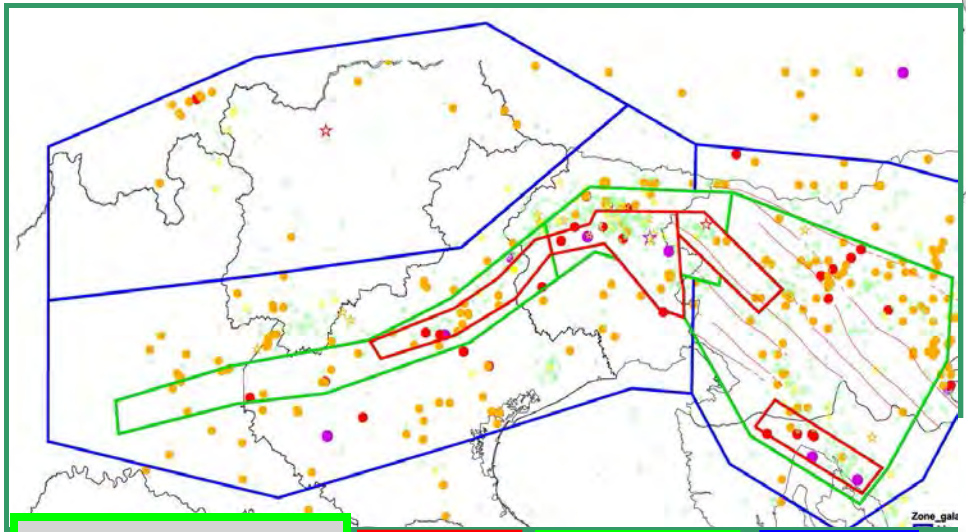


ZS4 del 1996



ZS9 del 2003

Seismogenic zonations for NE Italy

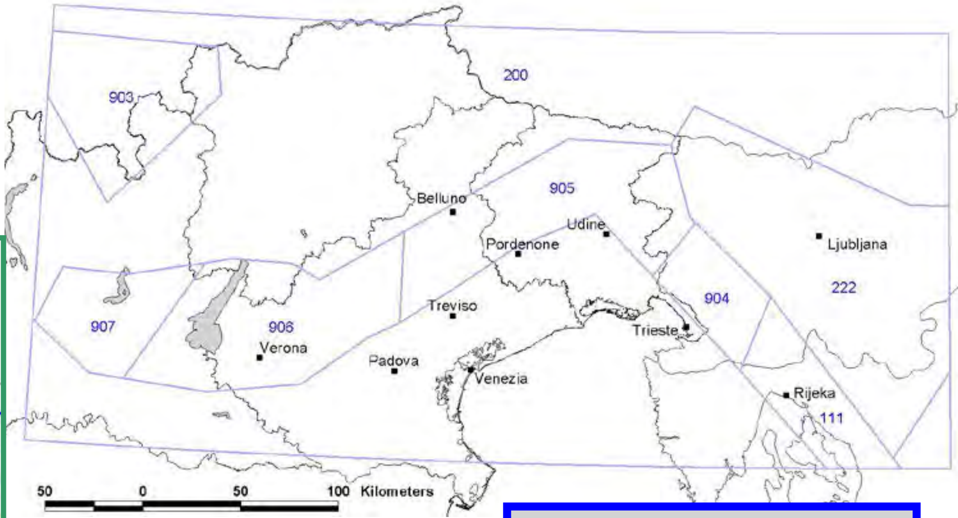


3LEV zonation

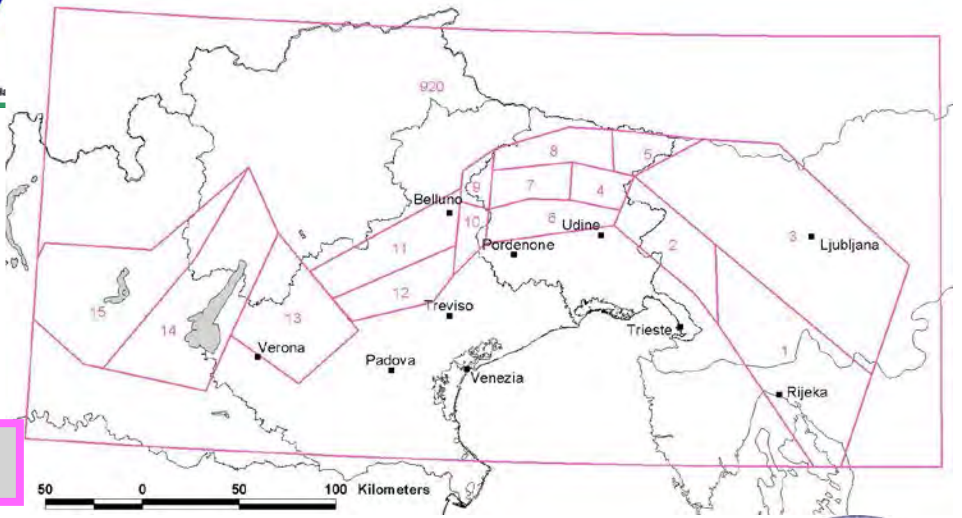
High Mag.

Medium Mag.

Low. Mag

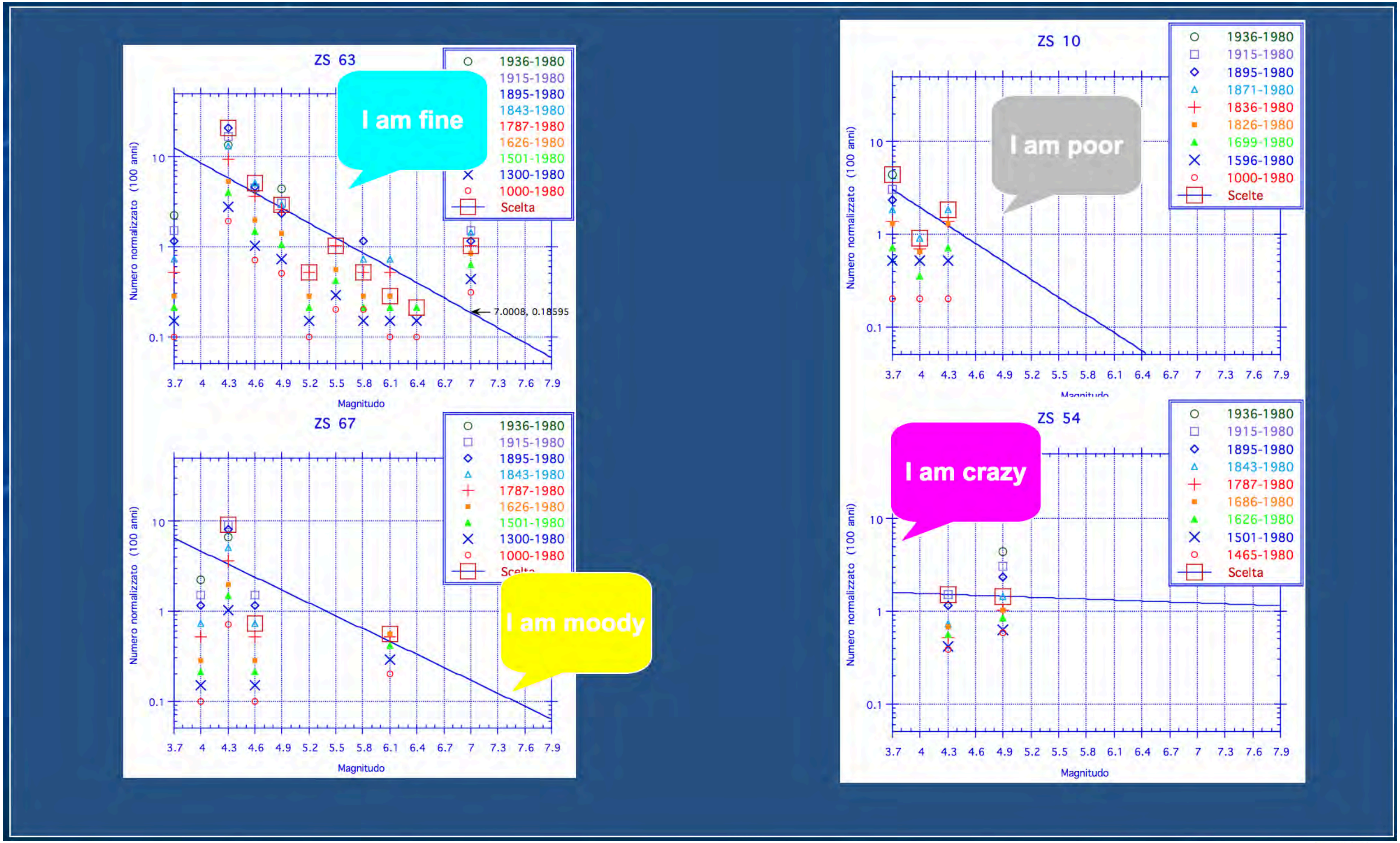


ZS9 zonation

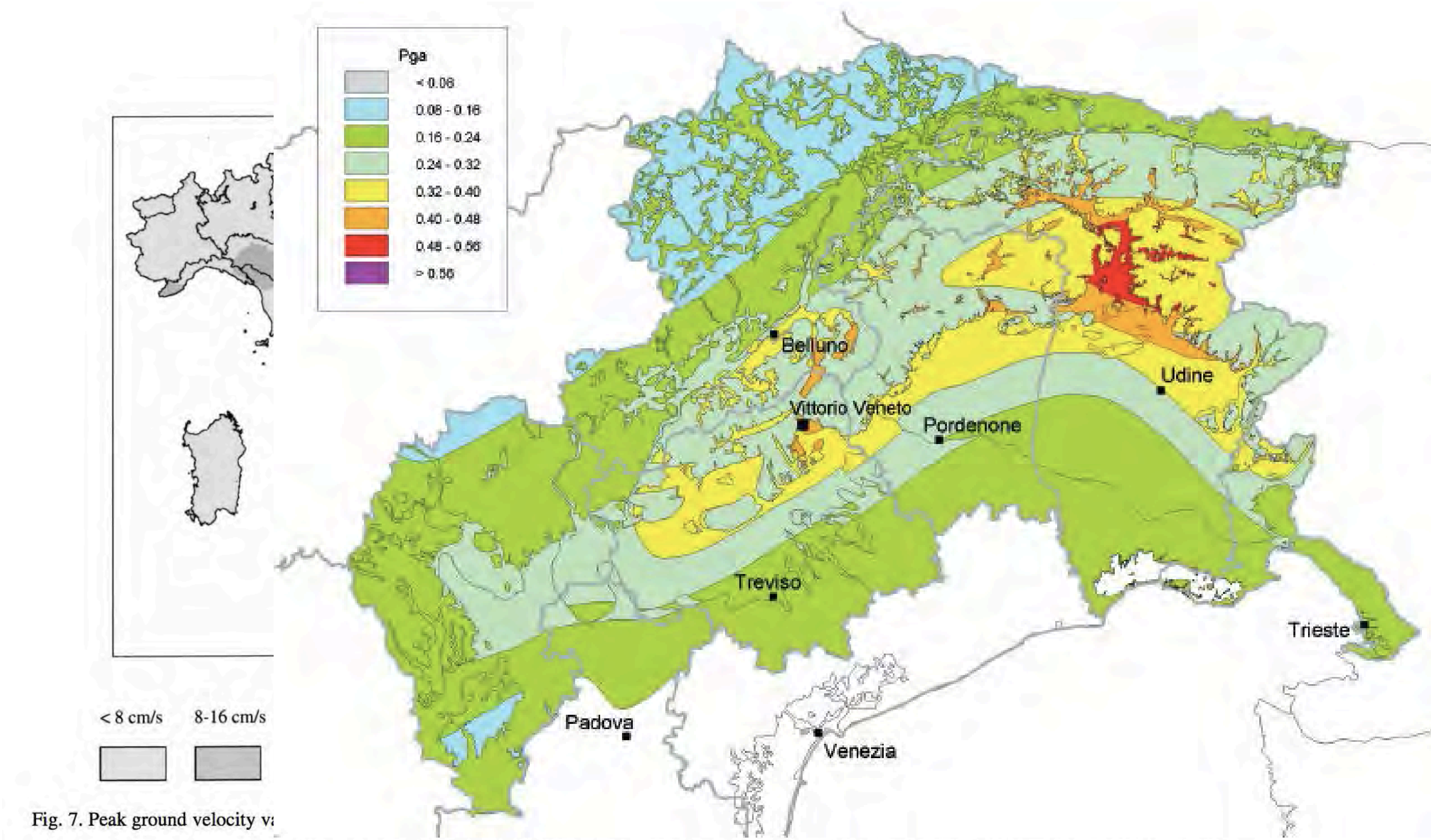


FRI zonation

Caratterizzazione della sismicità



Mappe nazionali e regionali con effetti di sito

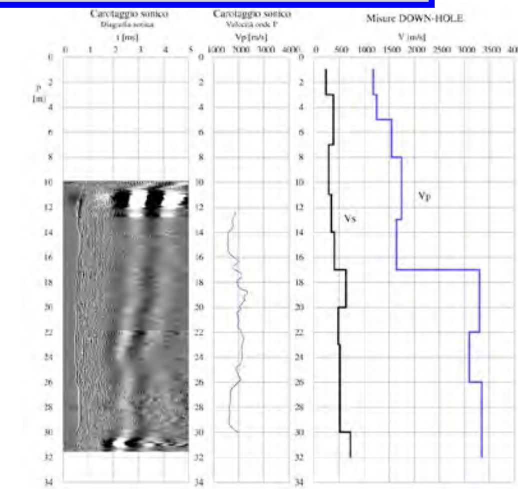


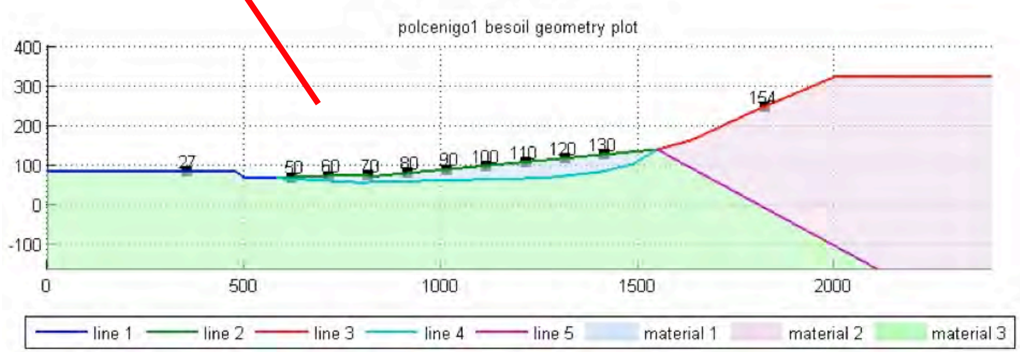
Slejko et al. (2008)

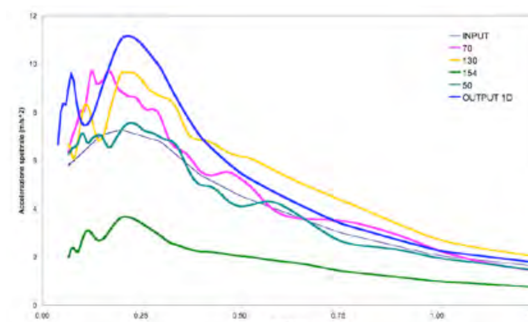
Amplification factors for the litho-types (1D and 2D modelling)

Test sites

Cross- and down-hole, sonic log, geoelectrics, reflection seismics



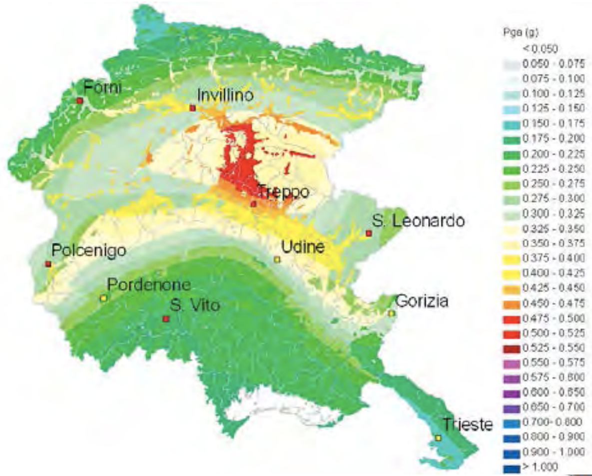


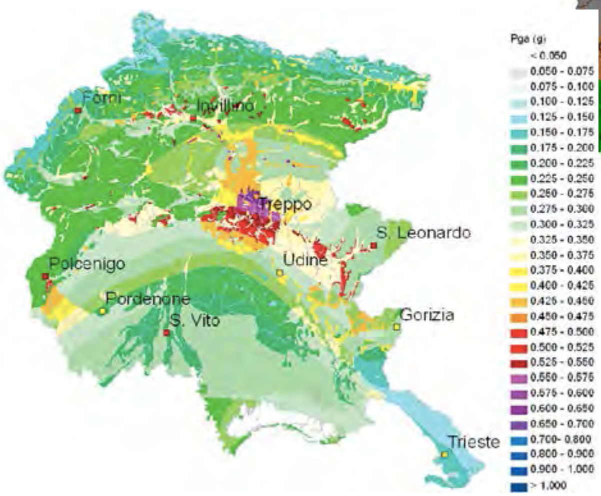


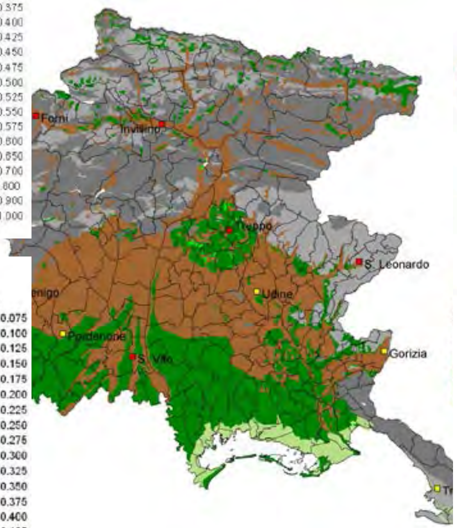
Amplification factors as ratio of the input and output areas of the response spectra between 0.1-0.5 s.

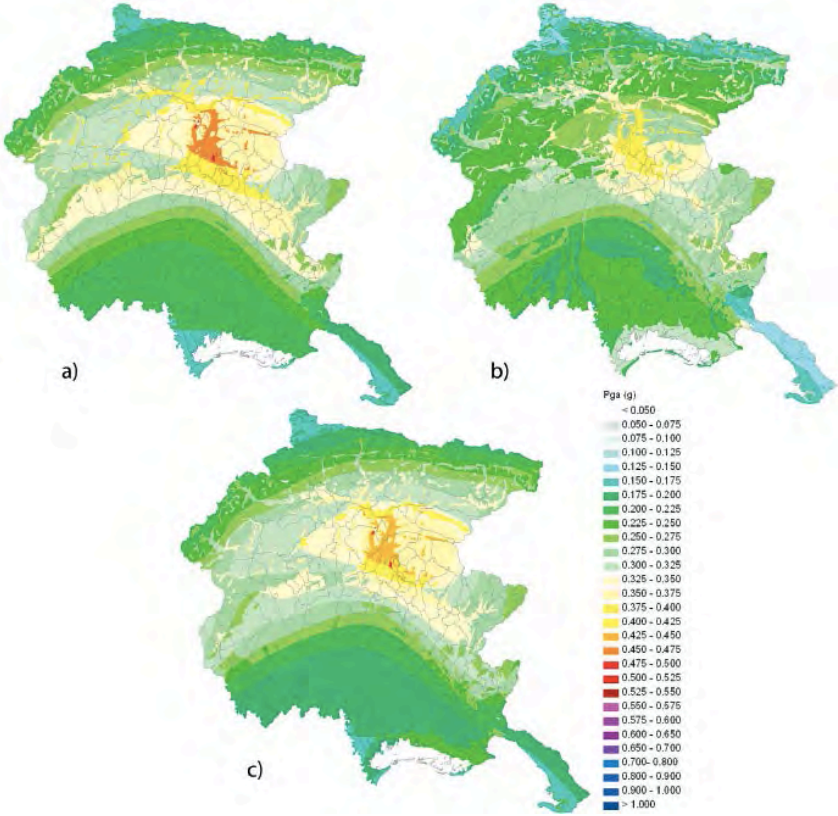
NEHRP Class	NEHRP Description	NEHRP V30 (m/s)	FaL NEHRP	FaL FVG	EC8 Class	EC8 V30 (m/s)
A	Hard rock	>1500	0.8	1		
B	Rock	760-1500	1.0	1	Rock	>800
C	Very dense soil and soft rock	360-760	1.2	1.2	Stiff	800-360
D	Stiff soil	180-360	1.5	1.7	Soft	360-180
E	Soft soil	<180	2.1	1.9	Very soft	<180

Soil hazard map for Friuli







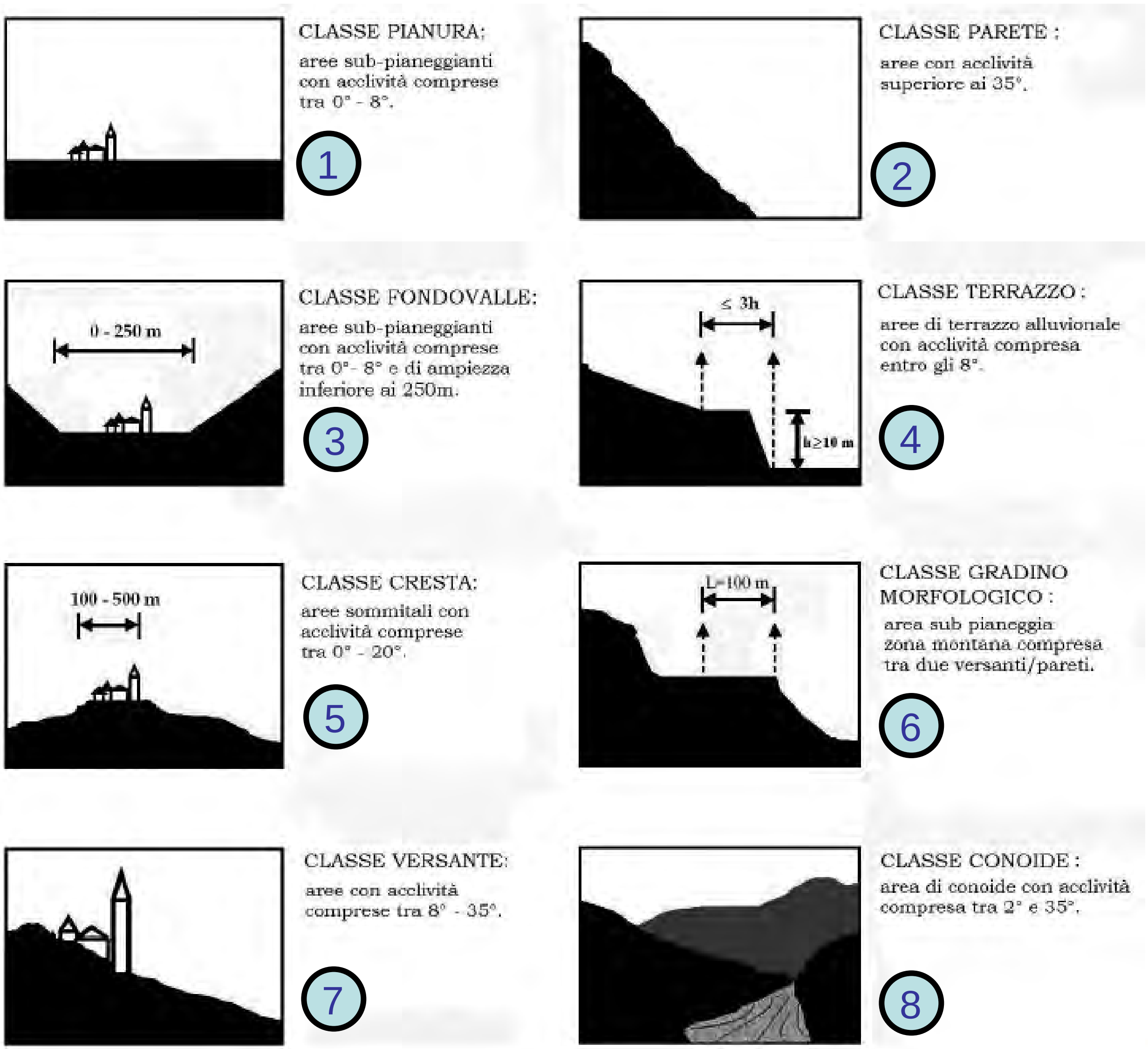


Soil seismic hazard map of Friuli Venezia Giulia (PGA with a 475-year return period) computed by considering:

1) different soil-dependent GMPEs
2) building code lithological AFs: a) Italian (Ministro delle Infrastrutture,2008); b) NEHRP (BSSC, 2004); c) EC8 (CEN, 2002)
3) regional litho-stratigraphic AFs

Slejko et al. (2011)

Amplification factors for the morpho-types



Amplification factors:

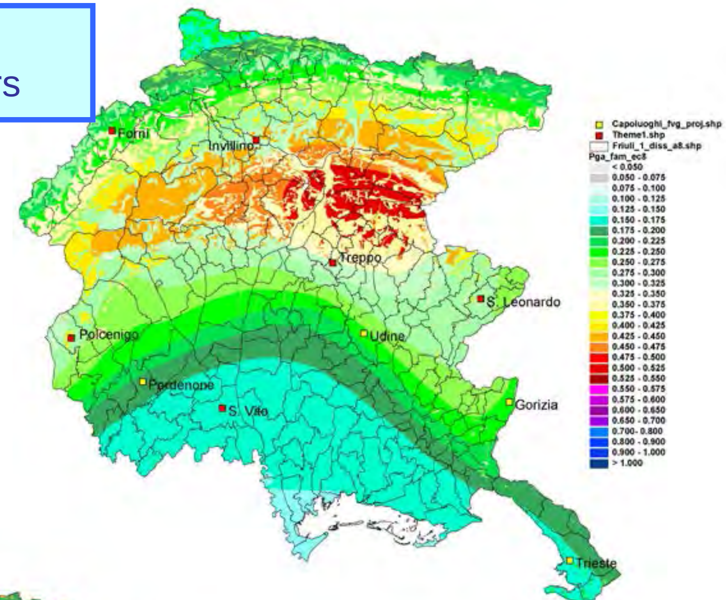
1 = 1.0
2 = 4.0
3 = 1.8
4 = 4.0
5 = 4.0
6 = 3.5
7 = 1.0
8 = 1.6

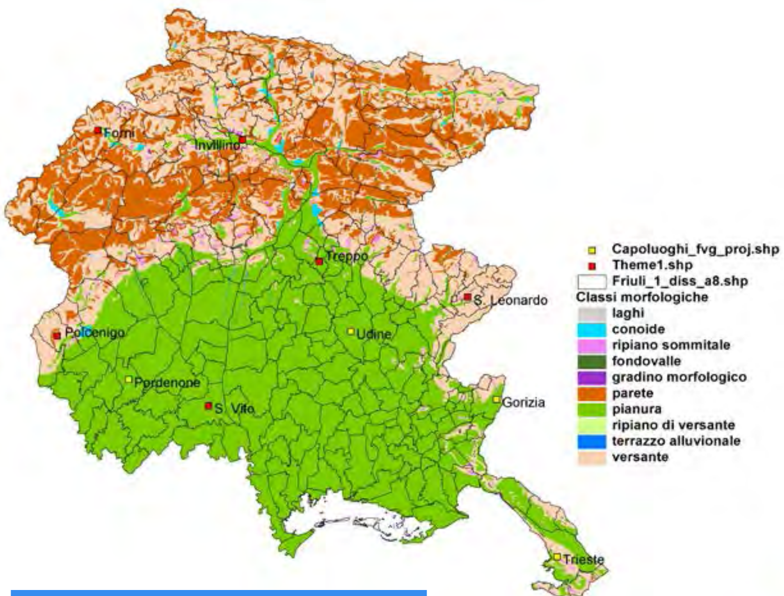
from the analysis of the damage observed during the ML6.4 1976 earthquake (Grimaz, 2006)

Hazard map from morphological amplification factors

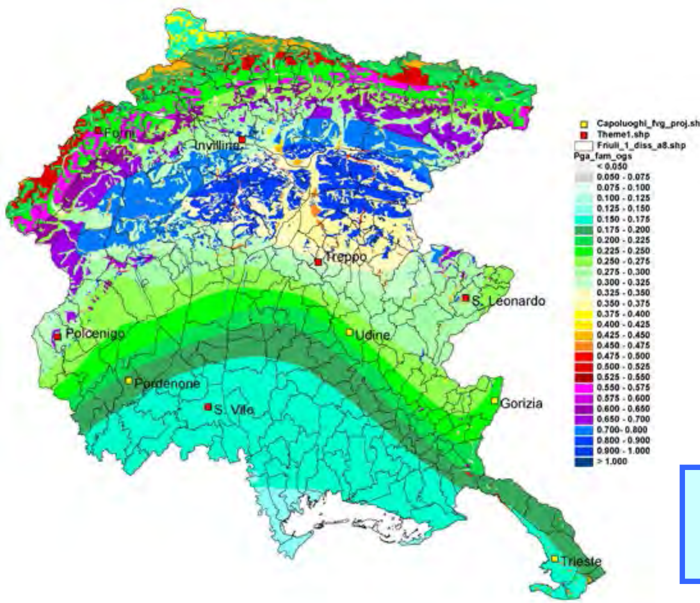
in terms of PGA with a 475-year return period

PGA with EC8 amplification factors





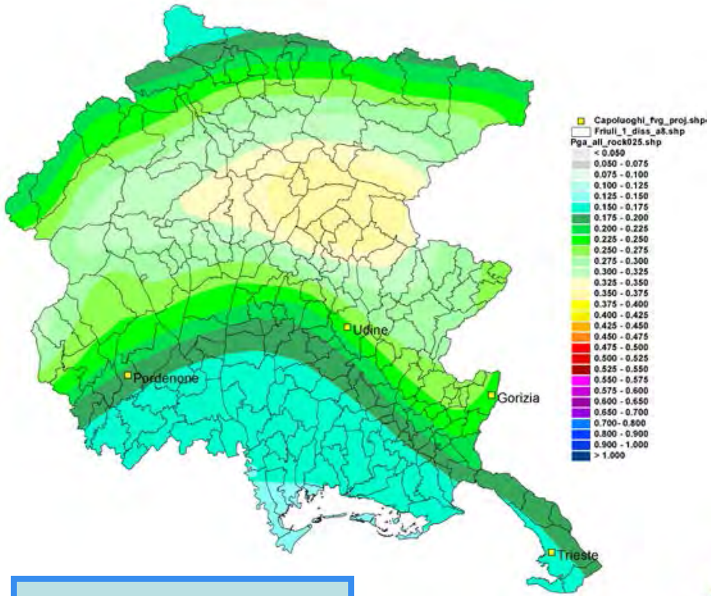
Morphological themes



PGA with OGS amplification factors

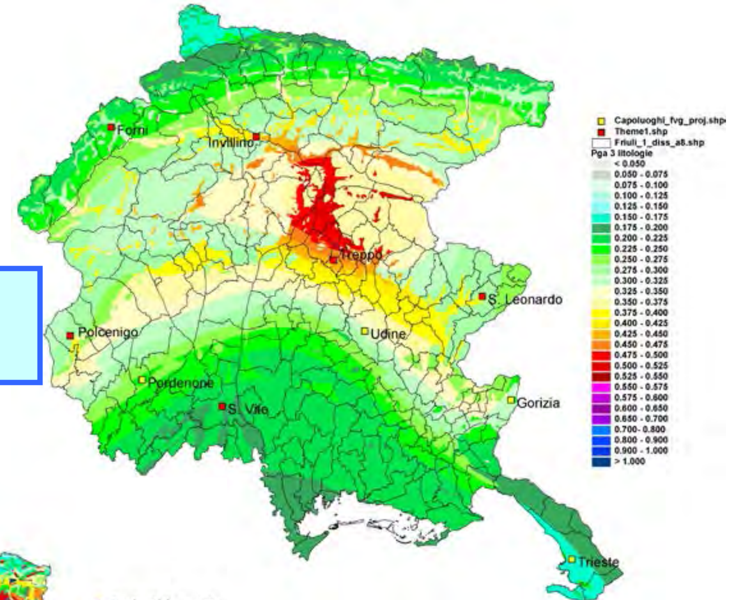
Site hazard map from lithological and morphological amplification factors

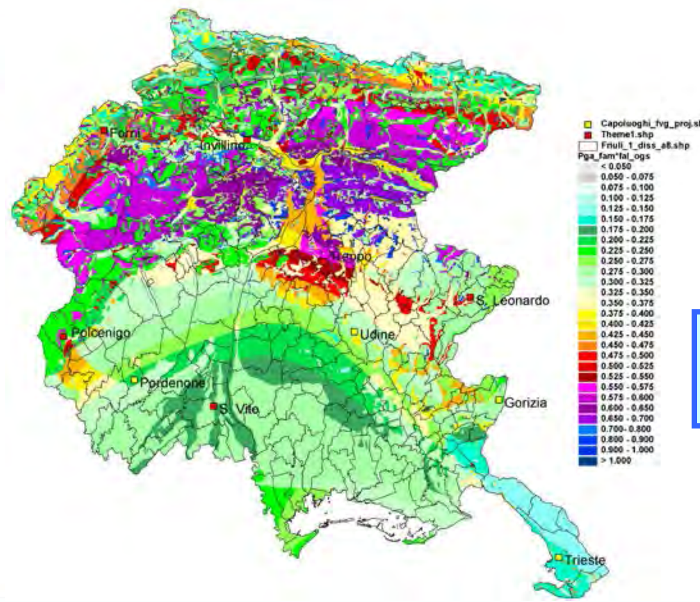
in terms of PGA with a 475-year return period



Rock hazard map

PGA with different attenuation relations





PGA with OGS amplification factors

"Building a culture of prevention is not easy…
the benefits are not tangible;
they are the disasters that did not happen"

Kofi Annan after the Bam earthquake