DIPARTIMENTO DI GEOSCIENZE

UNIVERSITÀ DEGLI STUDI DI PADOVA

Environmental and engineering Geophysics

Engineering & Environmental

Near surface Geophysics Applications

Site Characterisation, pollutions sites, Foundations problems, cavities, subsoil structures, pavement roads, agronomy, archeology, etc

Geophysics for the RISKS

Hydrologic risk

Levees structures, leakages, rivers, subsoil hydrology, seawater intrusion, landslides

Volcanic risk

??

EARTHQUAKES risk

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Introduction to the Applied Seismology

(i.e. the applied geophysics for the earthquakes risk)

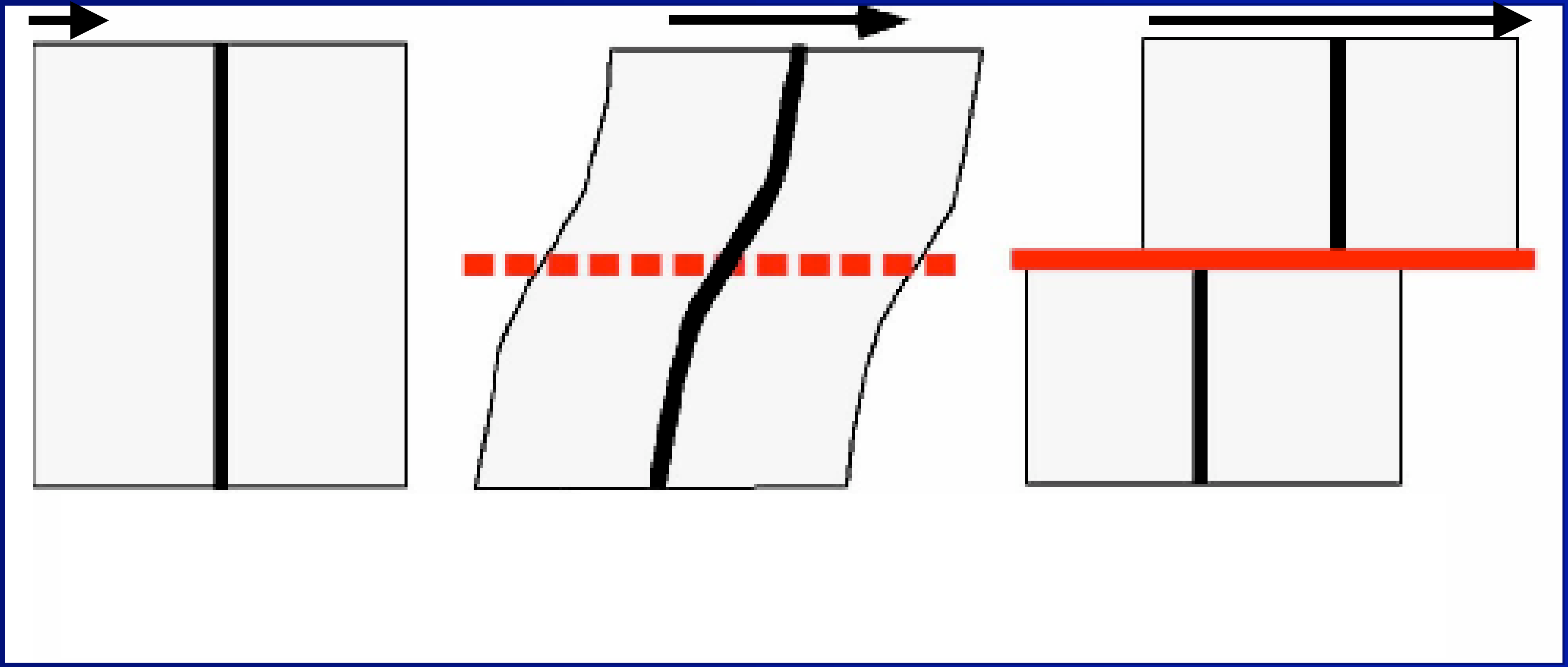
Outline

Part 1
- The Earthquake
- The world seismicity
- The Italian seismicity
- The euro code norms
- How we can act

Part 2
- The seismic local response (SLR)
- The applied geophysics methods for the SLR
- case histories

Earthquake ?

Initial Stress - Strain growth - Rupture



Reid elastic rebound model

Rupture mechanism

Griffith, 1921

Stress

$$R_{\alpha\alpha} = R\frac{\sinh 2\alpha\ (\cosh 2\alpha - \cosh 2\alpha_0)}{(\cosh 2\alpha - \cos 2\beta)^2}, \quad (1)$$

$$R_{\beta\beta} = R\frac{\sinh 2\alpha\ (\cosh 2\alpha + \cosh 2\alpha_0 - 2\cos 2\beta)}{(\cosh 2\alpha - \cos 2\beta)^2}, \quad (2)$$

$$S_{\alpha\beta} = R\frac{\sin 2\beta\ (\cosh 2\alpha - \cosh 2\alpha_0)}{(\cosh 2\alpha - \cos 2\beta)^2}, \quad (3)$$

In homogenus media

Strain

$$\left.\begin{aligned} \frac{u_\alpha}{h} &= \frac{c^2 R}{8\mu}\{(p-1)\cosh 2\alpha - (p+1)\cos 2\beta + 2\cosh 2\alpha_0\} \\ \frac{u_\beta}{h} &= 0 \end{aligned}\right\} \quad (4)$$

Max stress crack

$$F = 2\int_0^R \frac{a_0 \cosh\frac{2R}{E} + b_0 \sinh\frac{2R}{E}}{a_0 \sinh\frac{2R}{E} + b_0 \cosh\frac{2R}{E}}\, dR$$

$$= E \log\left(\cosh\frac{2R}{E} + \frac{a_0}{b_0}\sinh\frac{2R}{E}\right), \quad (21)$$

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Rupture genesis
Fluid interactions play fundamental role F

FRACTURE CHARACTERISATION USING STATISTICAL ROCK PHYSICS *Hudson, 1997*

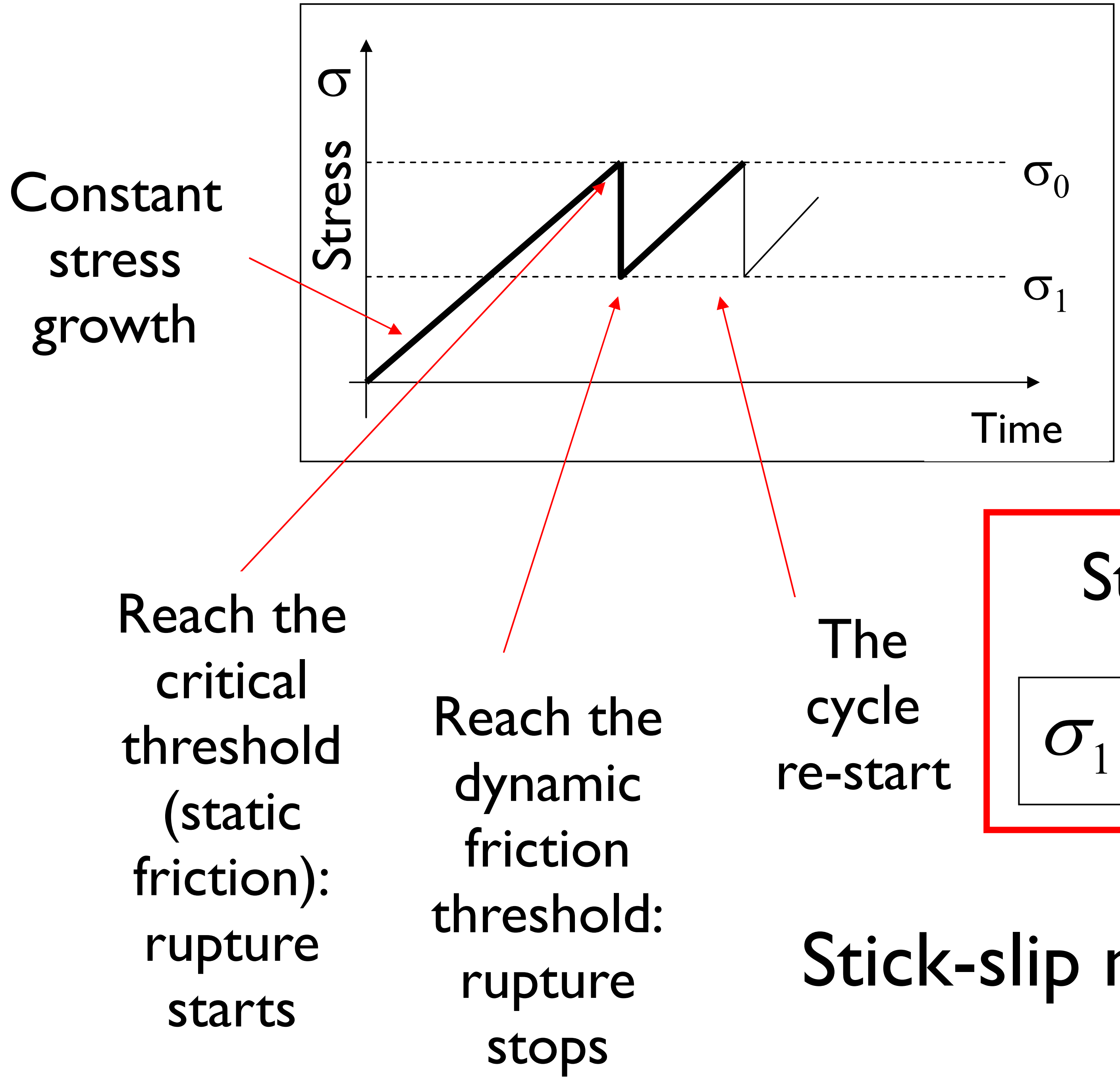
$$
\begin{pmatrix}
(\lambda+2\mu)\left(1-\frac{\lambda+2\mu}{\mu}eU_{33}\right) & \lambda\left(1-\frac{\lambda+2\mu}{\mu}eU_{33}\right) & \lambda\left(1-\frac{\lambda+2\mu}{\mu}eU_{33}\right) & 0 & 0 & 0 \\
\lambda\left(1-\frac{\lambda+2\mu}{\mu}eU_{33}\right) & (\lambda+2\mu)\left(1-\frac{\lambda^2}{\mu(\lambda+2\mu)}eU_{33}\right) & \lambda\left(1-\frac{\lambda}{\mu}eU_{33}\right) & 0 & 0 & 0 \\
\lambda\left(1-\frac{\lambda+2\mu}{\mu}eU_{33}\right) & \lambda\left(1-\frac{\lambda}{\mu}eU_{33}\right) & (\lambda+2\mu)\left(1-\frac{\lambda^2}{\mu(\lambda+2\mu)}eU_{33}\right) & 0 & 0 & 0 \\
0 & 0 & 0 & \mu & 0 & 0 \\
0 & 0 & 0 & 0 & \mu(1-eU_{11}) & 0 \\
0 & 0 & 0 & 0 & 0 & \mu(1-eU_{11})
\end{pmatrix} \quad (2.3)
$$

STOCHASTIC MODELS

Based on simplified assumptions

and a good knowledge of mechanical parameters….?

Simplified Approach



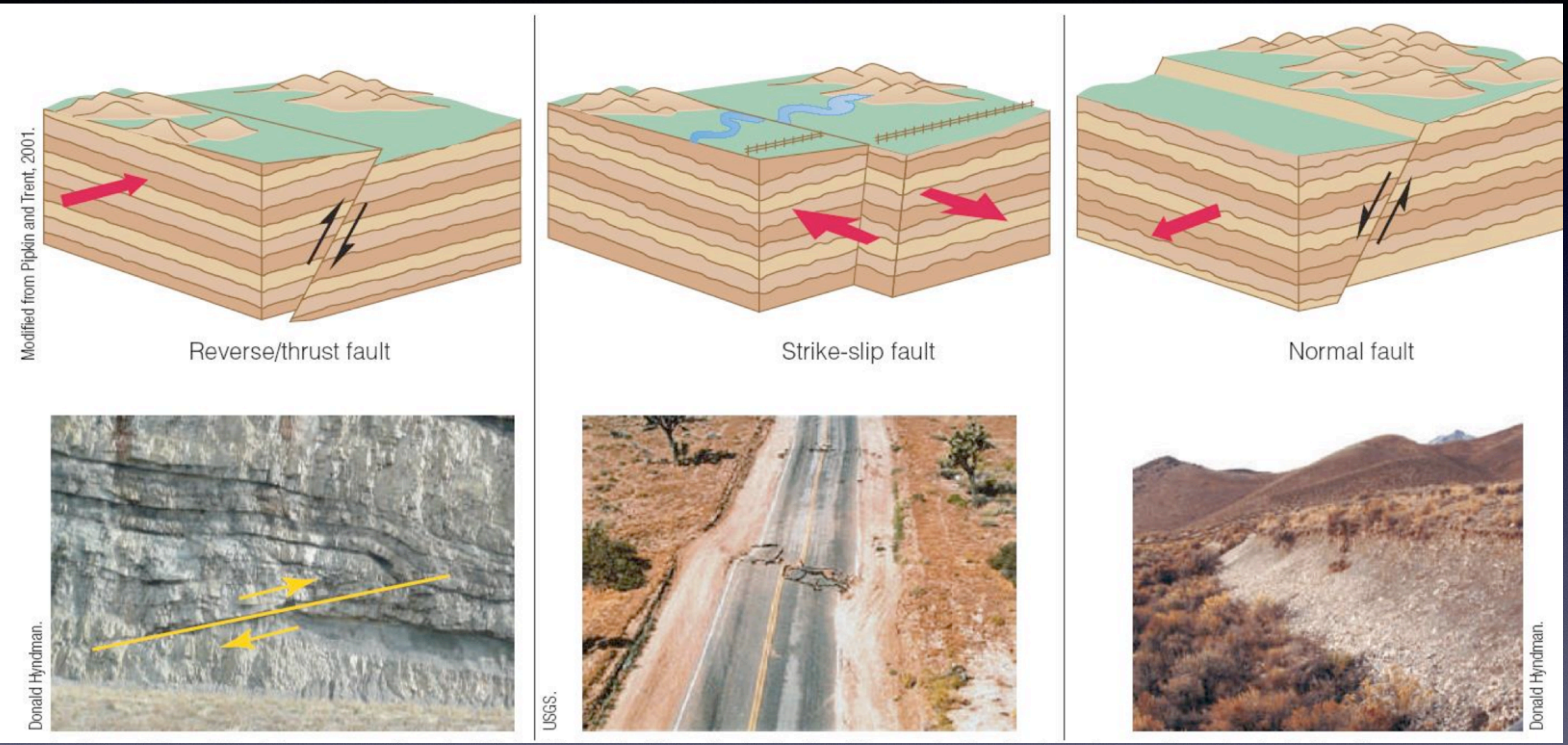
Stress drop

$$\sigma_1 - \sigma_0 = \Delta\sigma$$

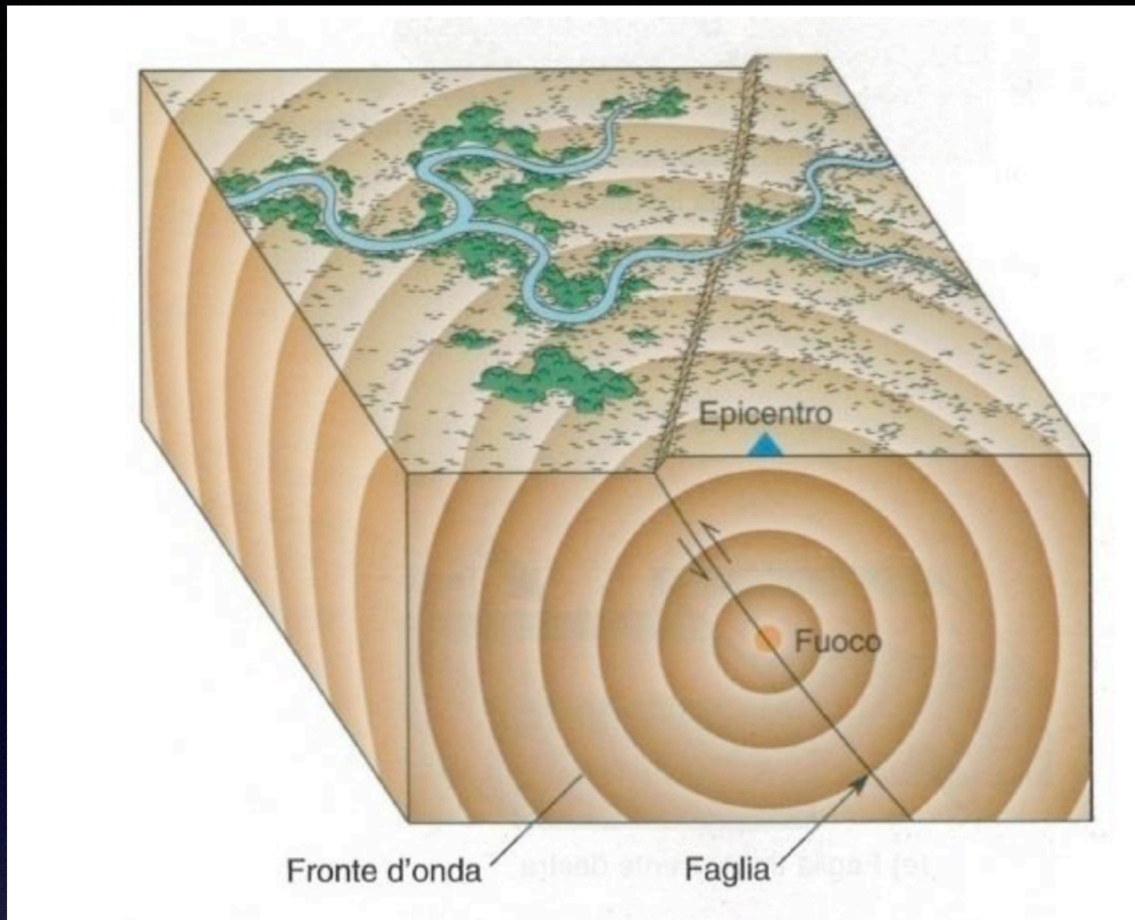
Stick-slip mechanism

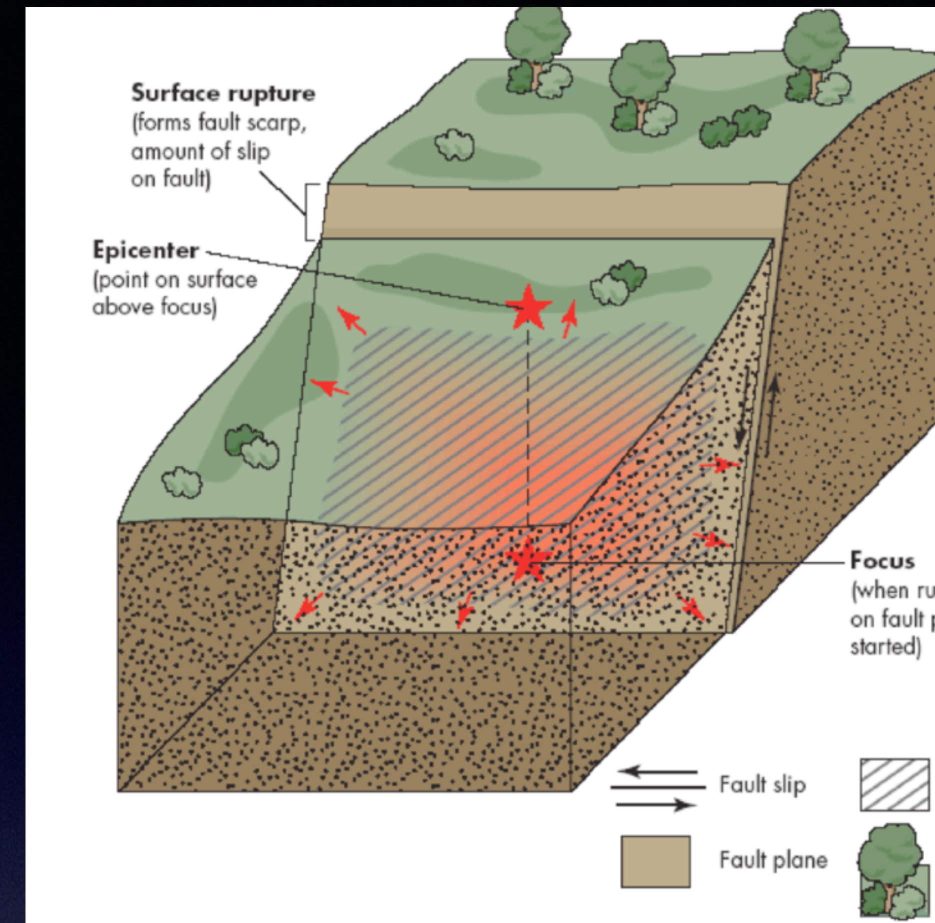
>> $\Delta\sigma$ >> Earthquake energy release

Rupture: energy release (mostly heat)



Different type of rupture: different type of faults



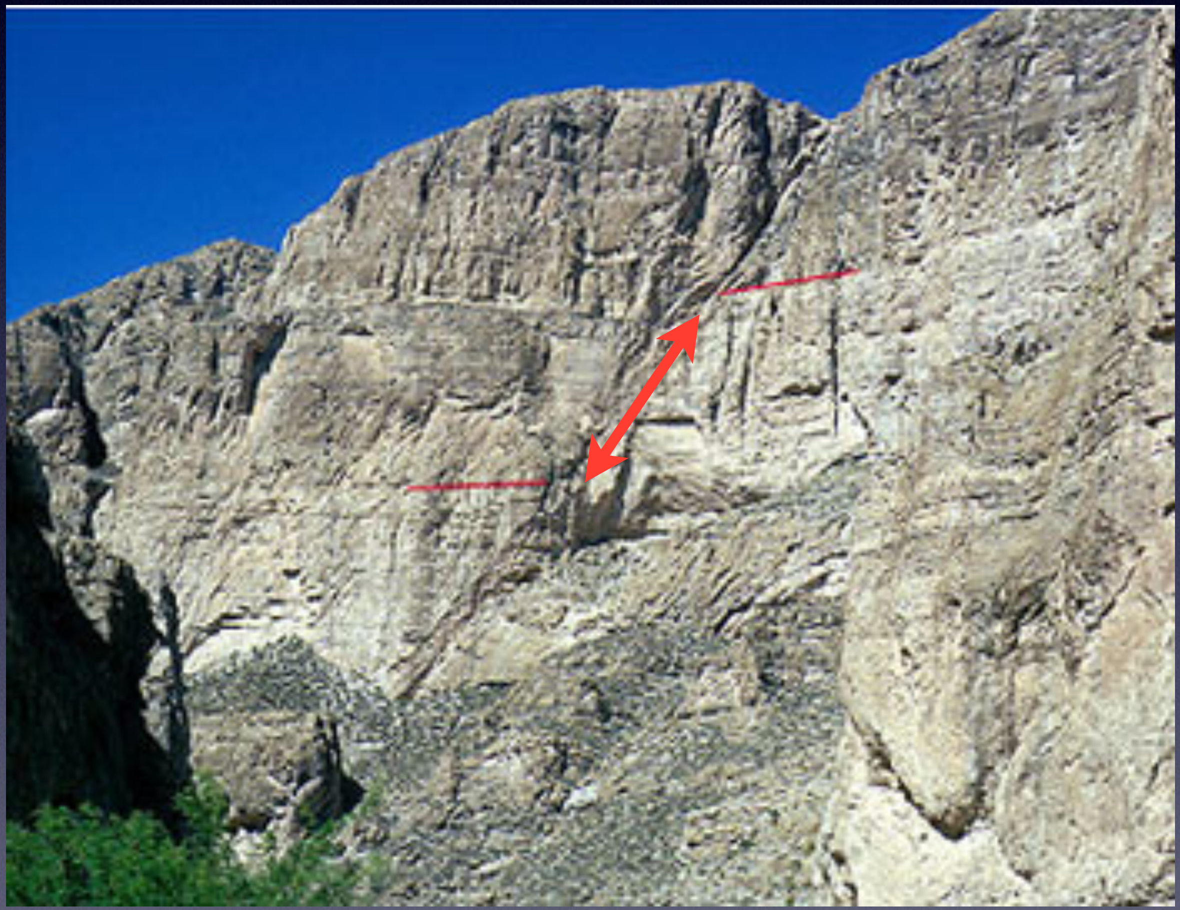


Bigger the rupture

Bigger the energy release

Ruptures of the past are NOT the todays problem

A

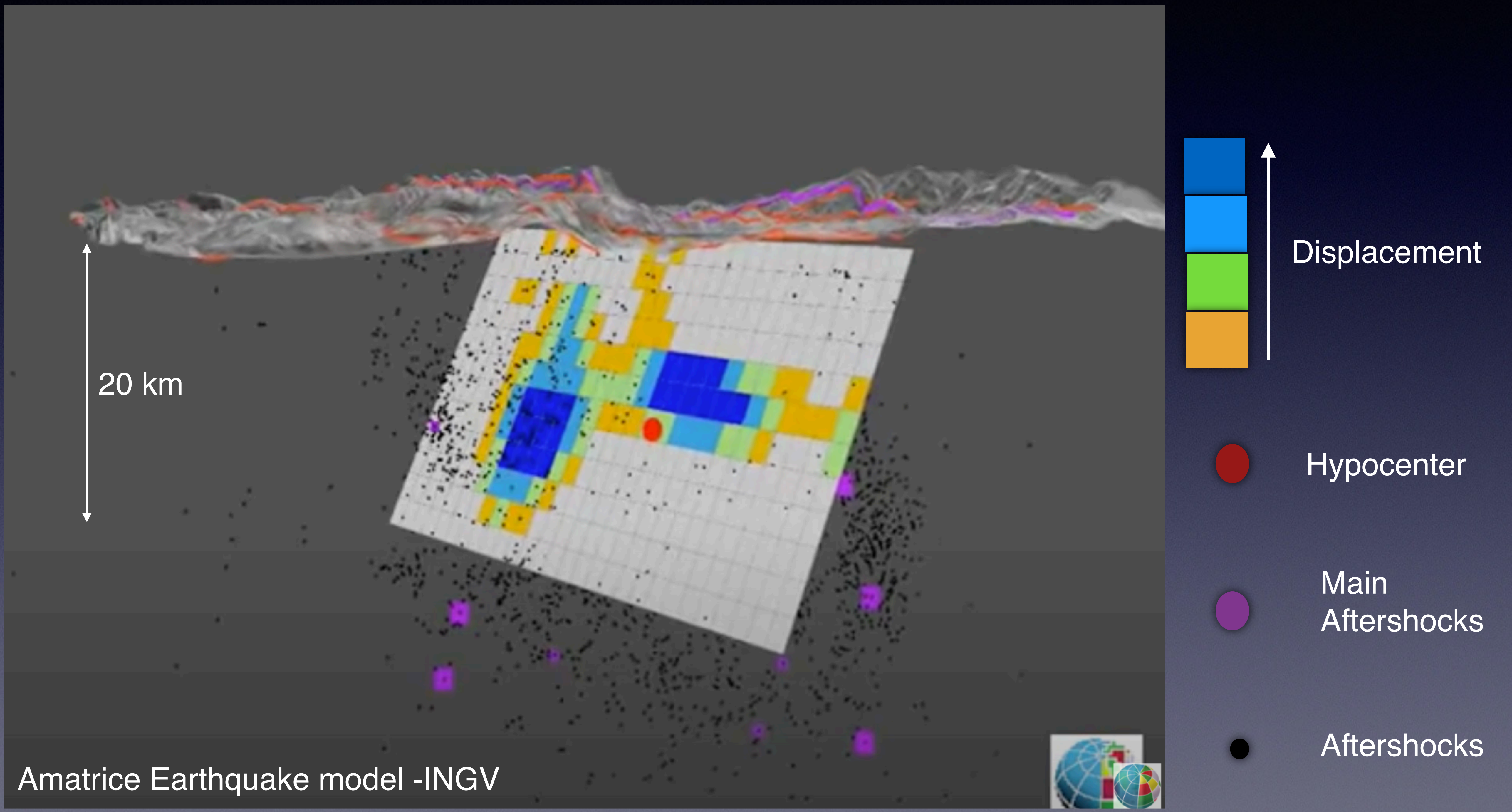


B

A is not more dangerous than B !

But we see a seismic fault?

most of the times only their effects….



What Earthquakes need?

1. Stress loading
2. rock fragile behaviour

Rheological conditions necessary for rupture

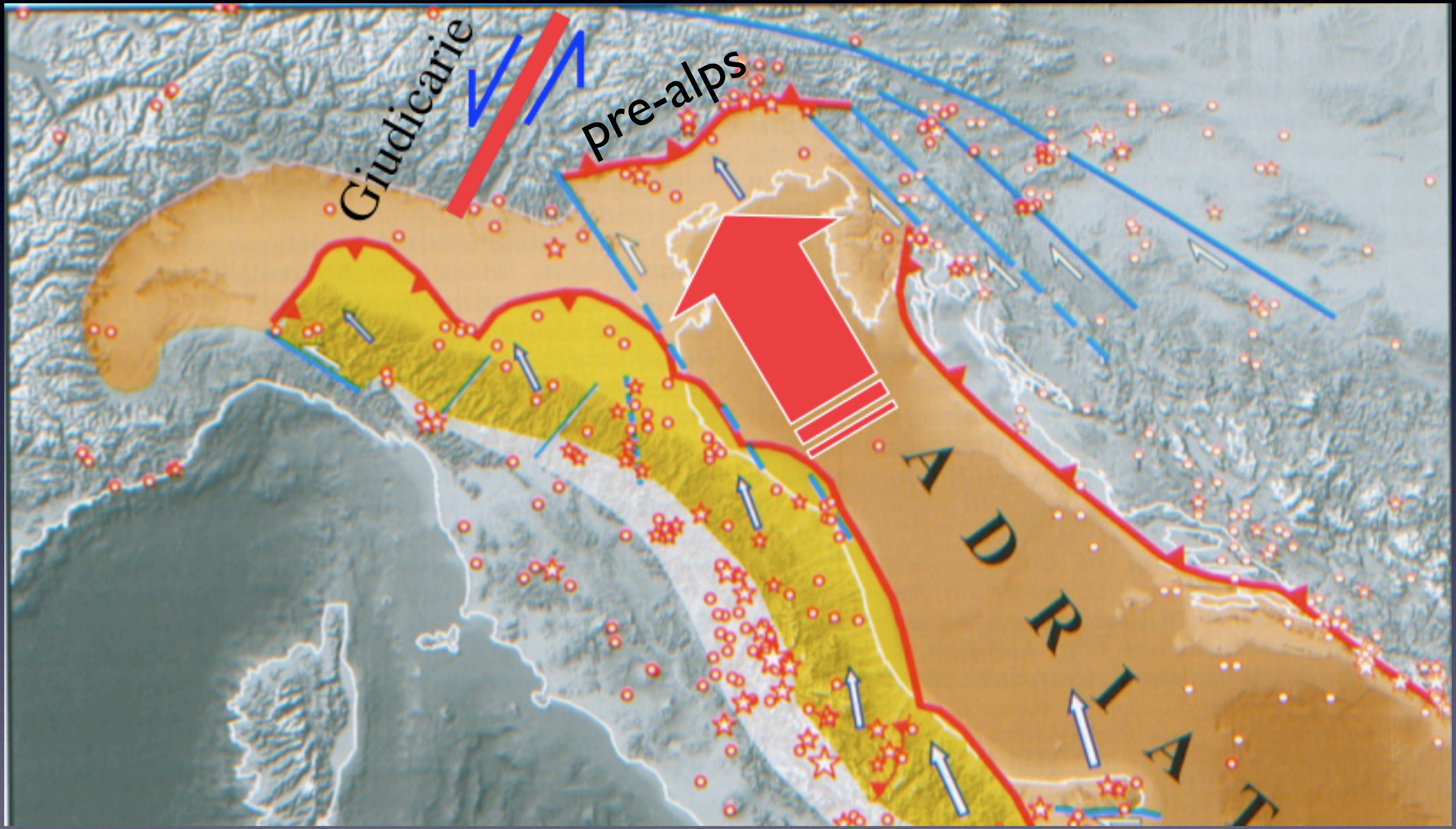
- $< T < P$
- H_2O !!
- *V stress*

e.g.
in Italy: 5 -20 Km depth
(upper crust)

e.g. while we are talking….

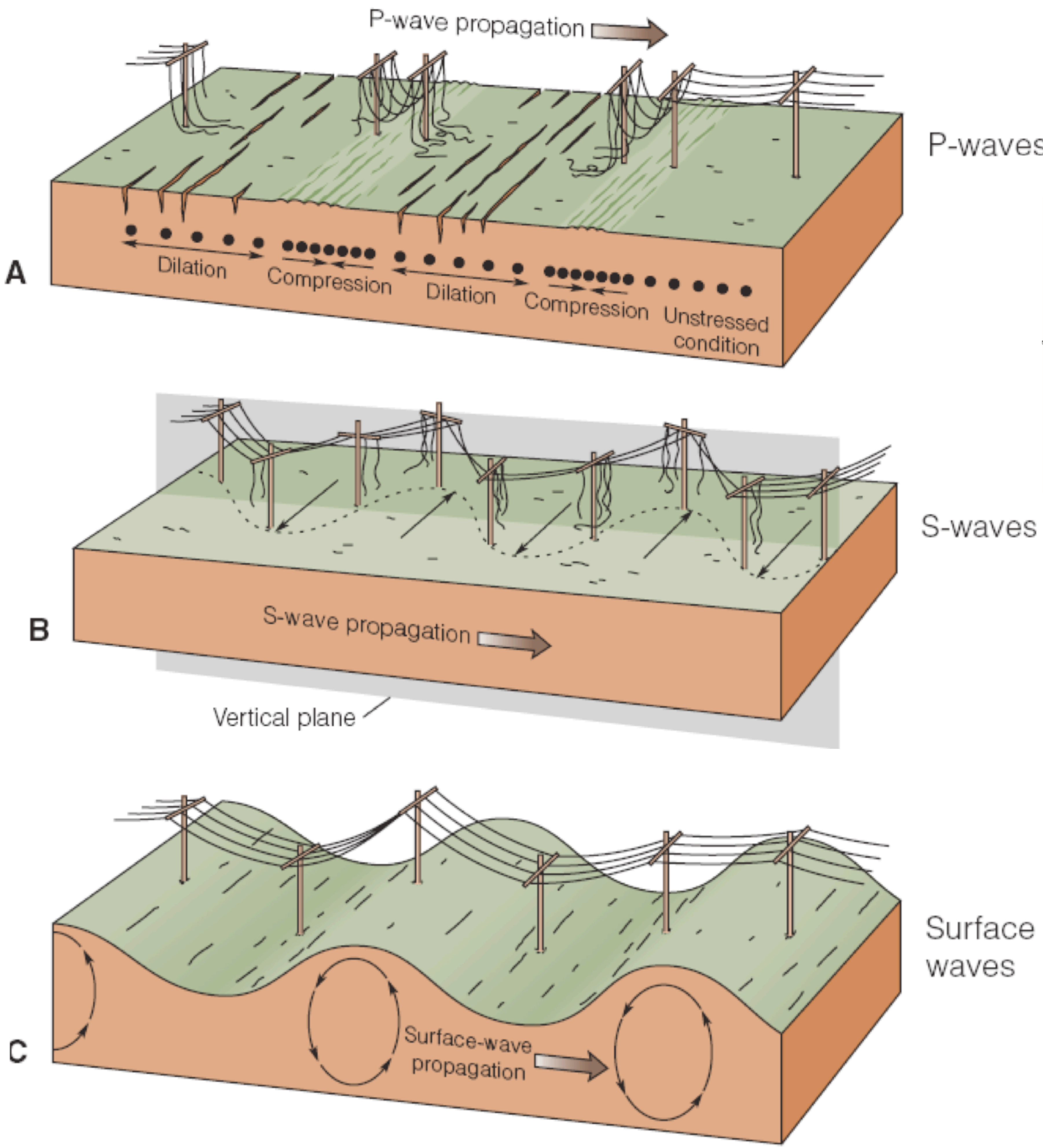
2. Stress loading

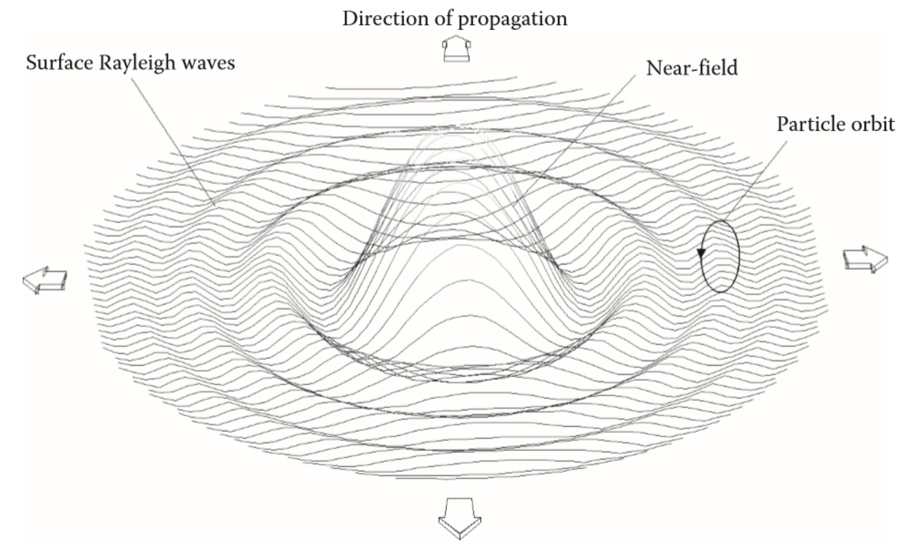
Adriatic micro-plate in subduction on European plate



3-6 mm/yr

The effect are the seismic waves





Body waves

P waves

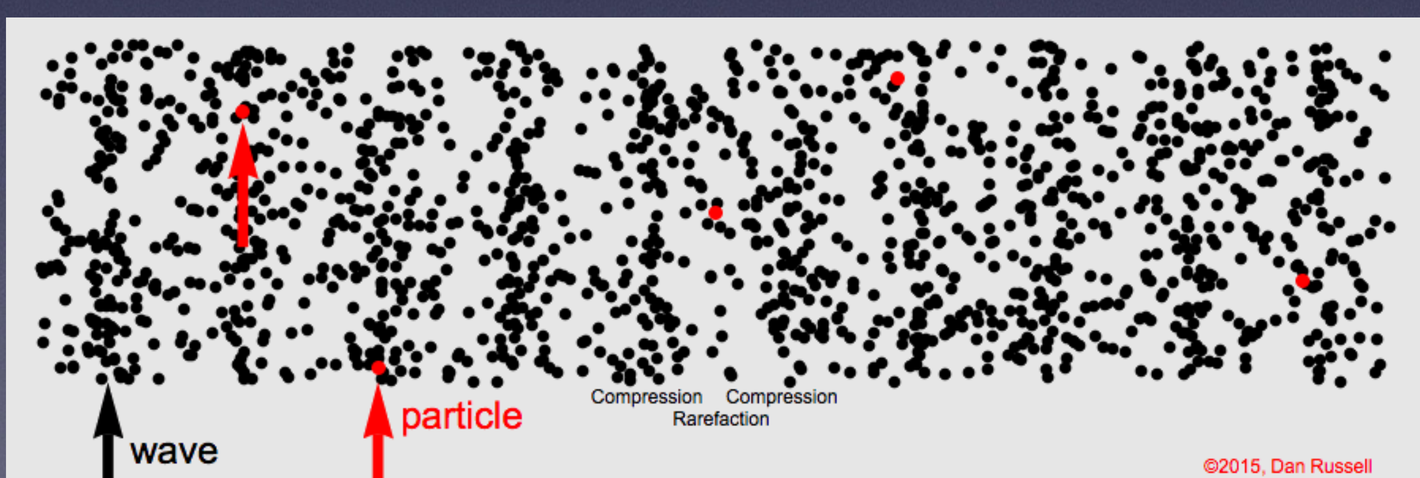
Compression and dilatation

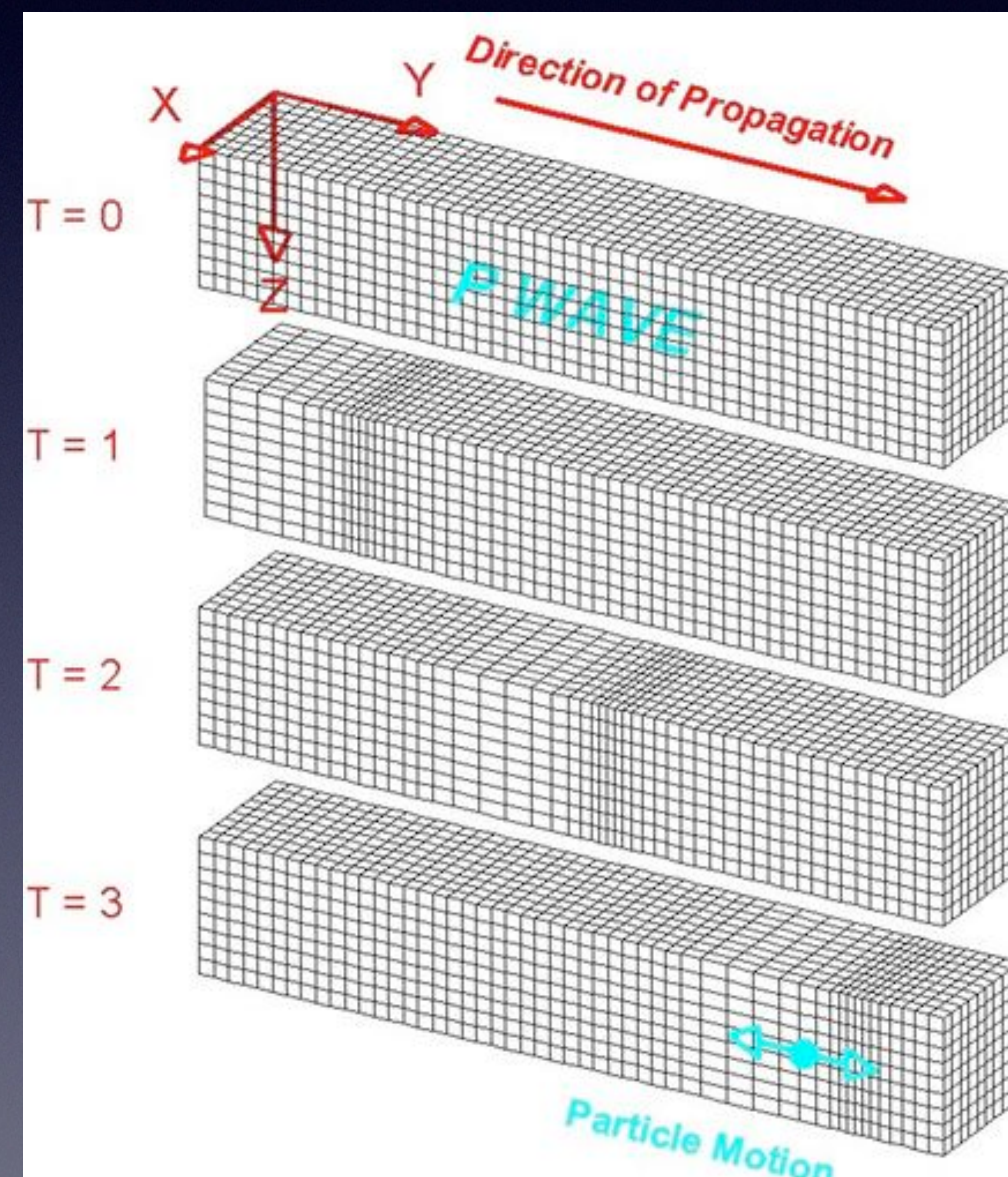
Compressibility modulus

$$v_p = \sqrt{\frac{K + \frac{4}{3}\mu}{\rho}}$$

Shear modulus

density





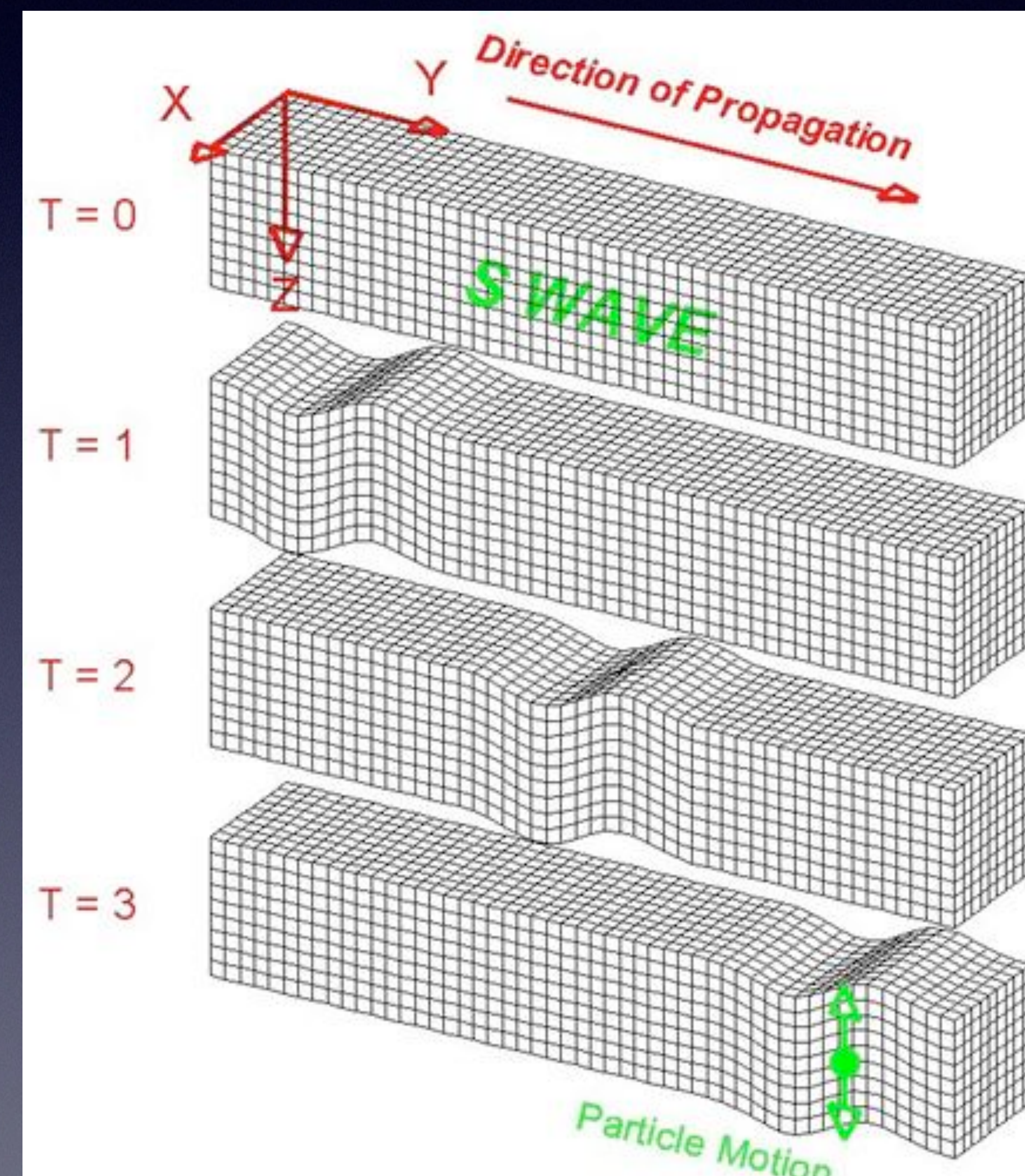
Body waves

S waves

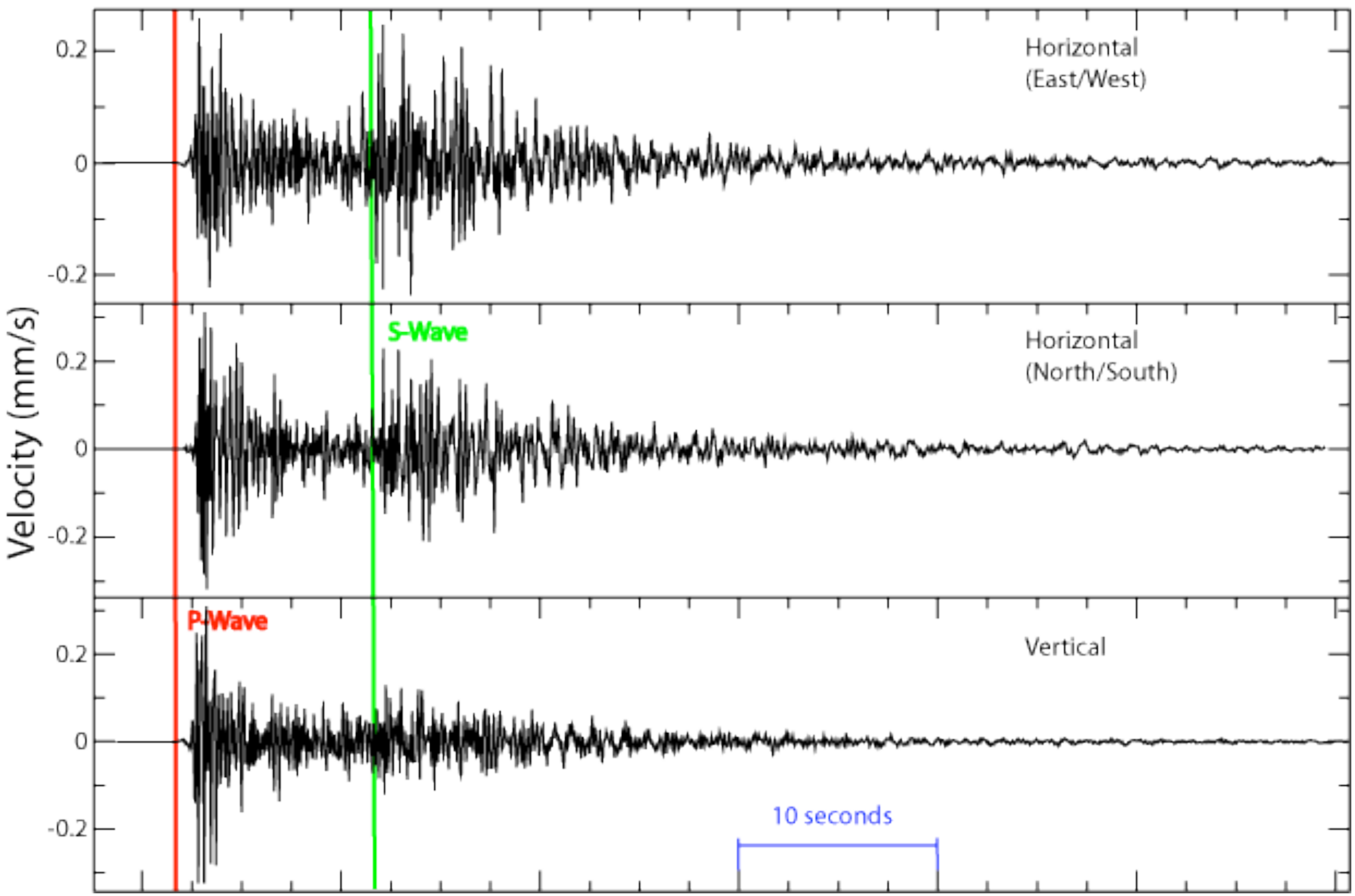
S waves perpendicular to the direction of propagation

$$v_s = \sqrt{\frac{\mu}{\rho}}$$

NB compressibility independent

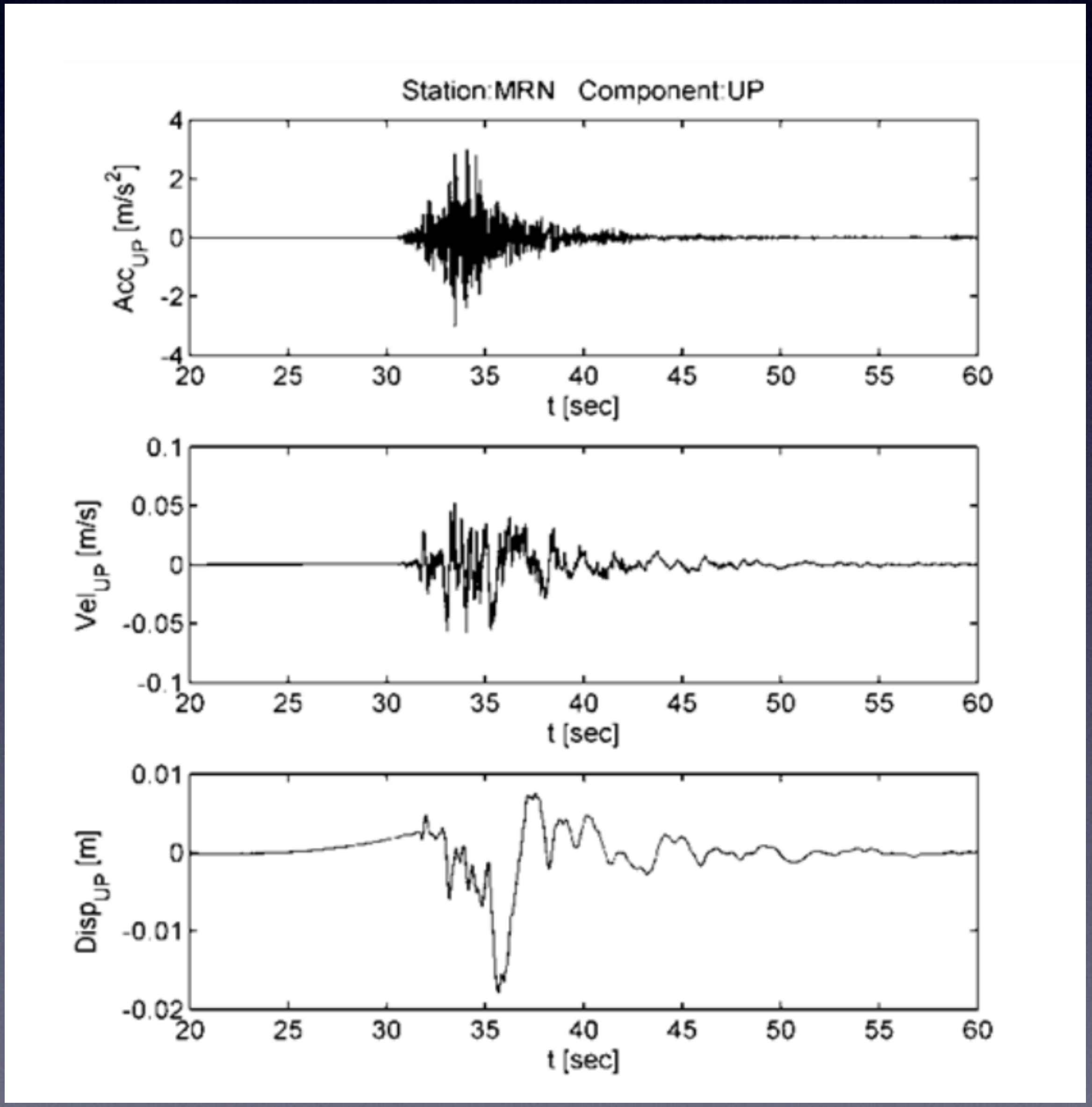


P and S waves on a seismogram



P and S waves on a seismogram

In Italy few seconds….



and the
early warning ?

2012 Emilia

Surface seismic waves

Due to constructive interference on the surface

2 types: Rayleigh waves
Love waves

Body waves travel in volumes (3d) surface waves on surface (2d):
Attenuation is lower f(distance r):

Surface waves Attenuation $r^{-0.5}$

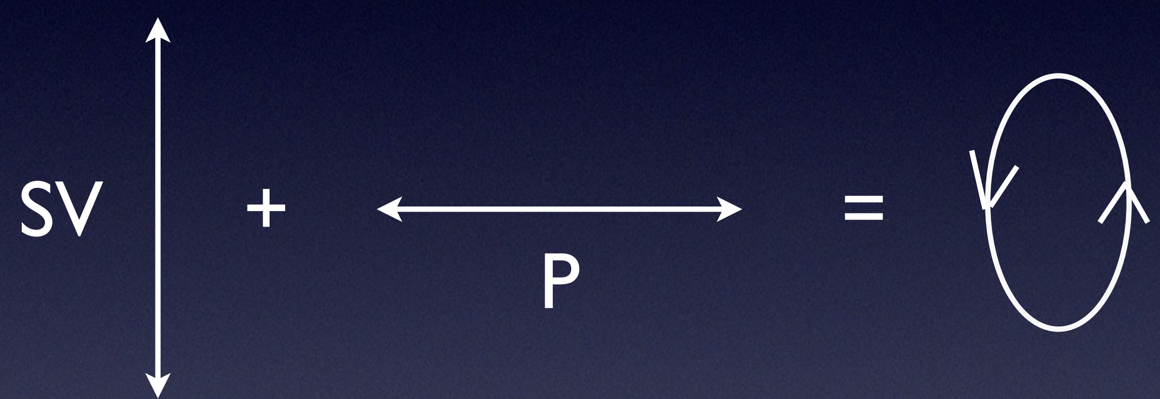
r^{-1} Body waves Attenuation

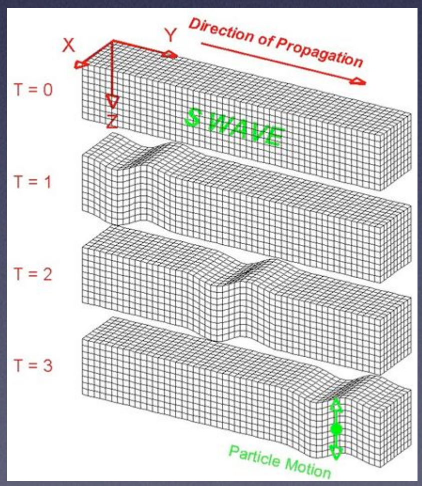
The most energetic events in a seismogram !

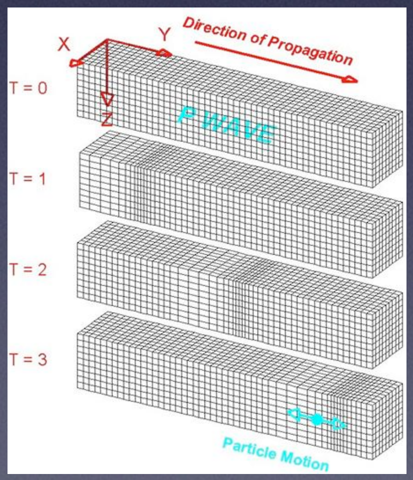
Rayleigh waves

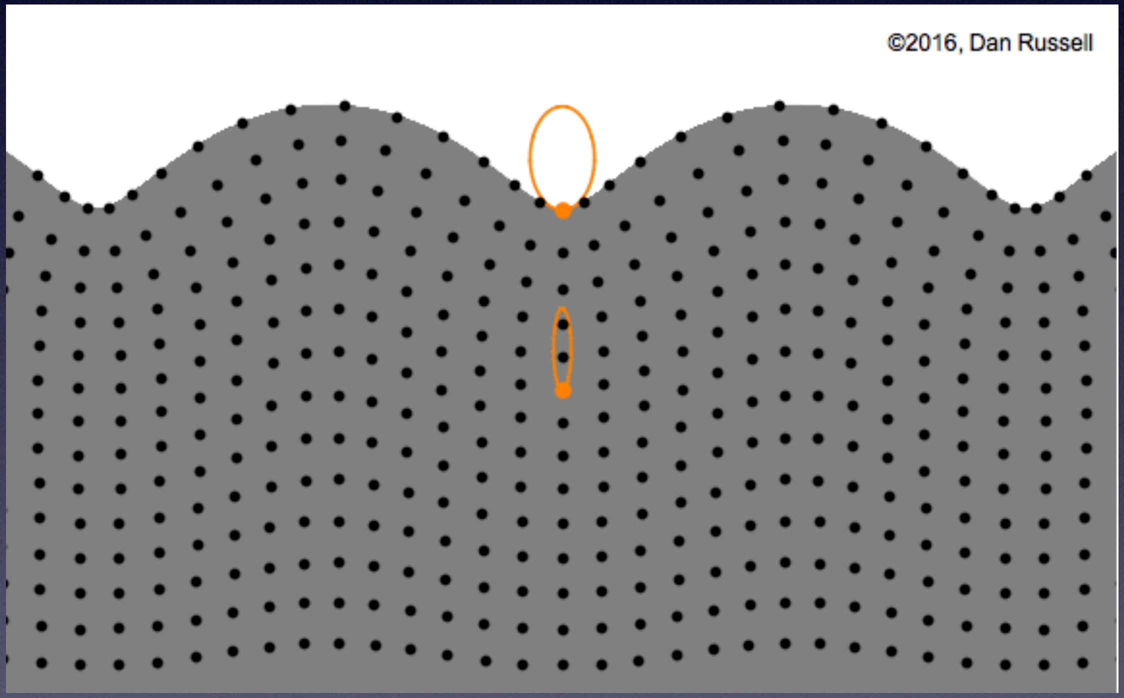
Generated from P waves and SV wave

(S waves vertically polarised)







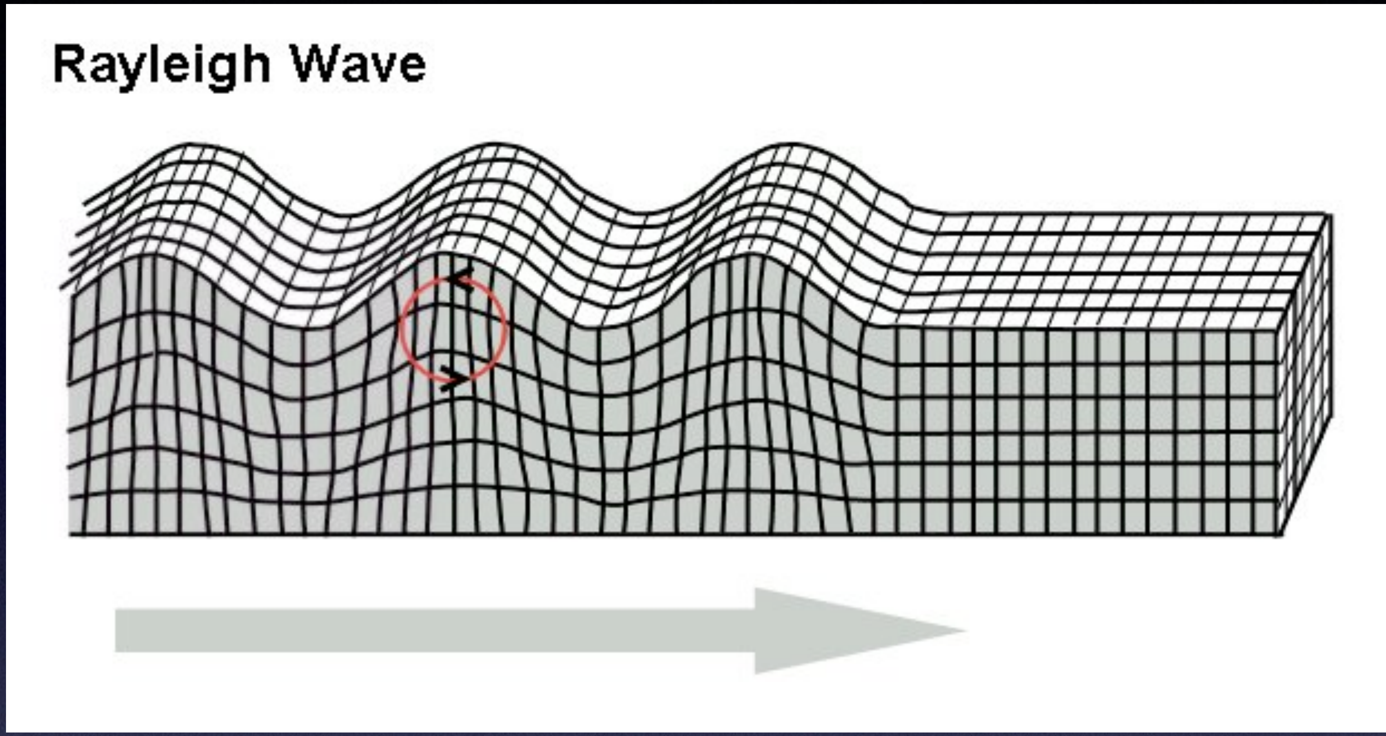


- Elliptical motion (prograde and retrograde)

Surface waves

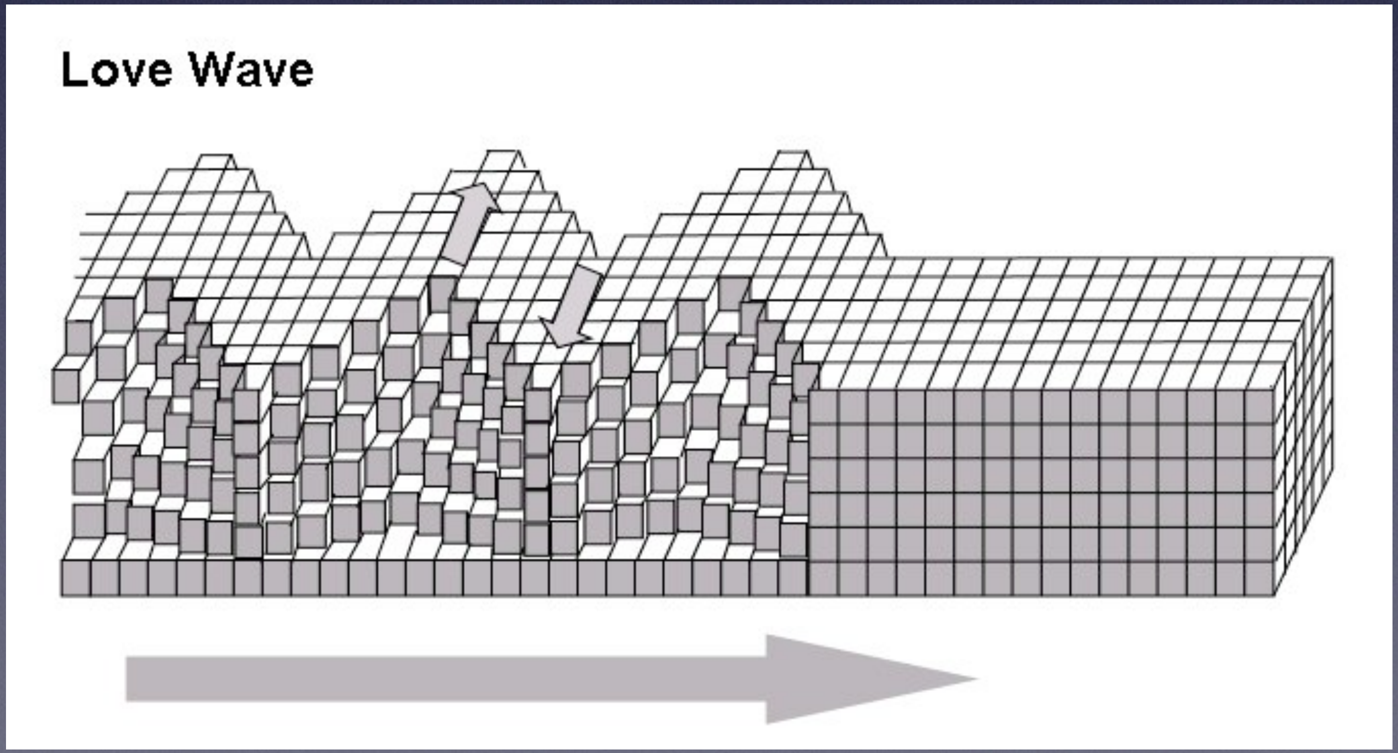
Rayleigh

Elliptical motion
(prograde and retrograde)

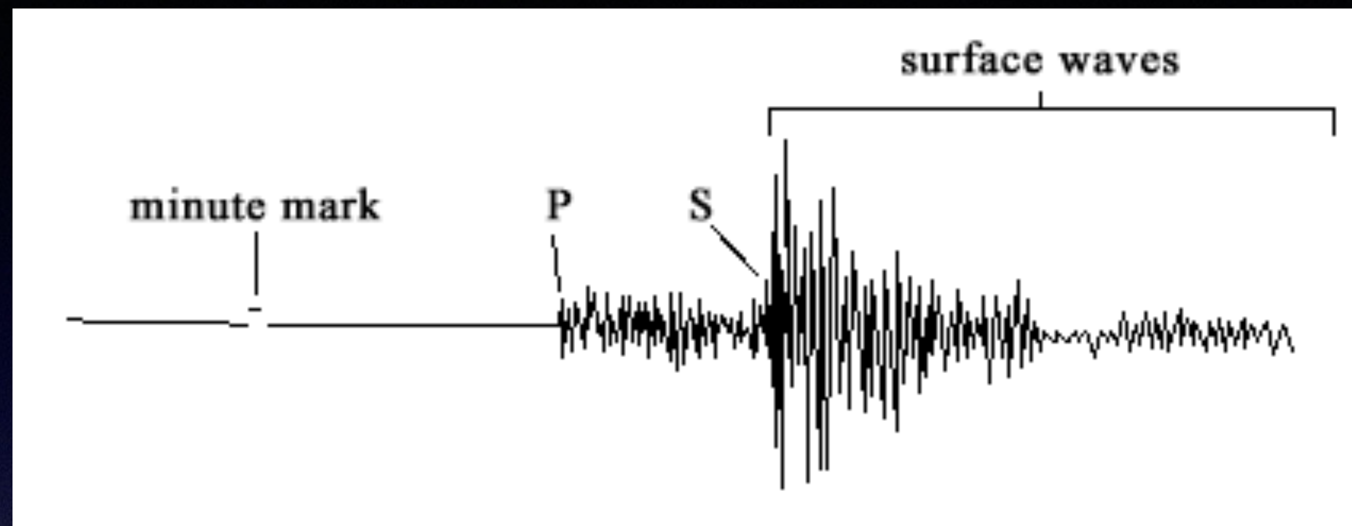


Love

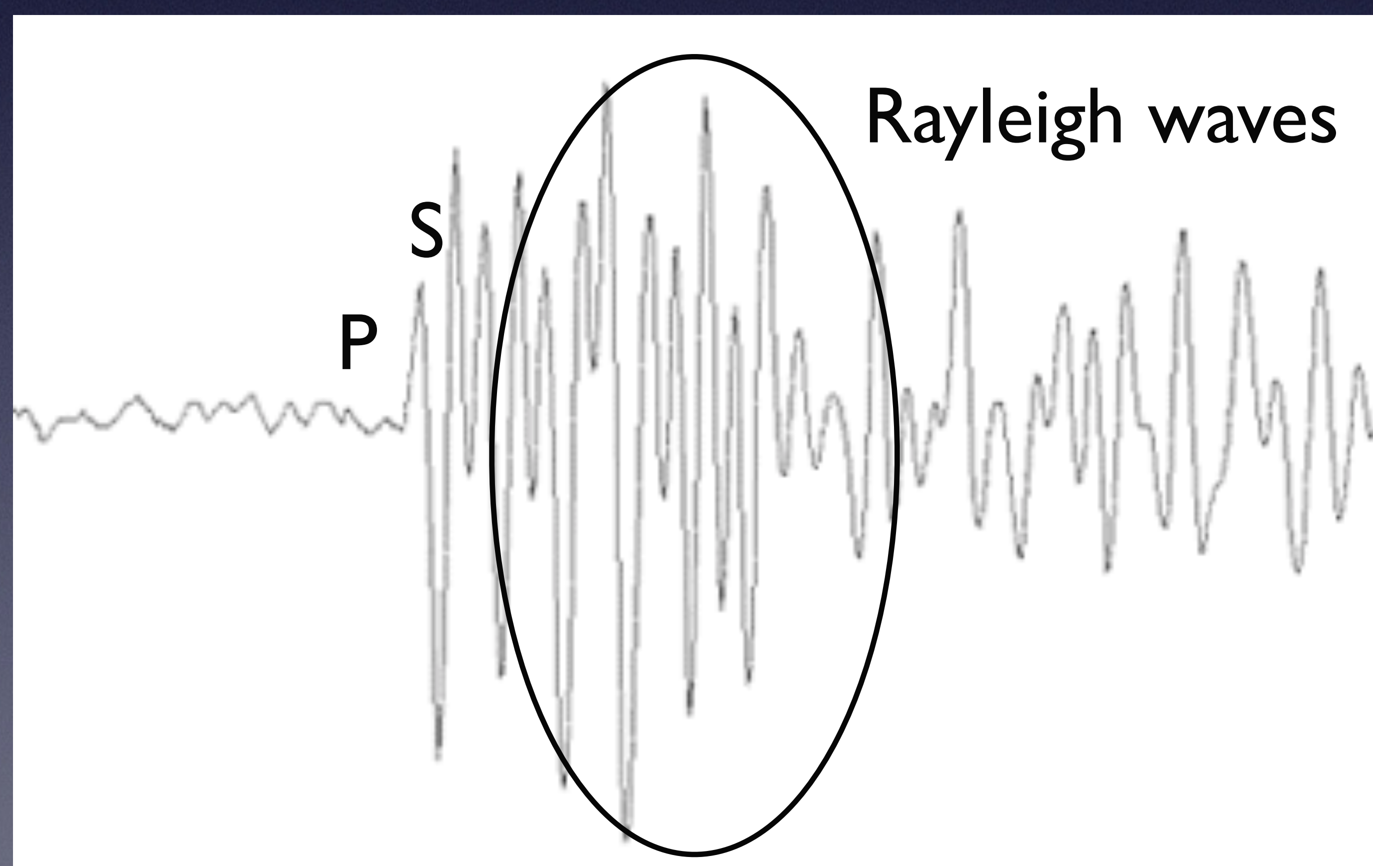
S waves horizontally polarized



Surface waves

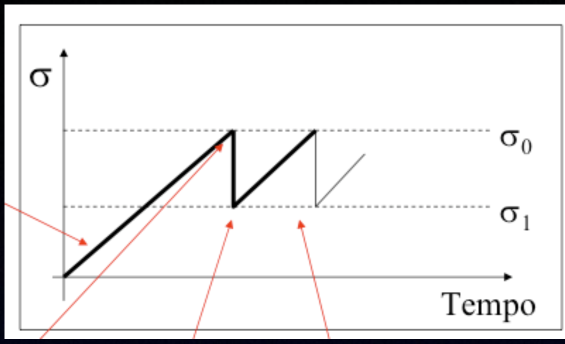


Earthquake



Hammer shot

- The Earthquake



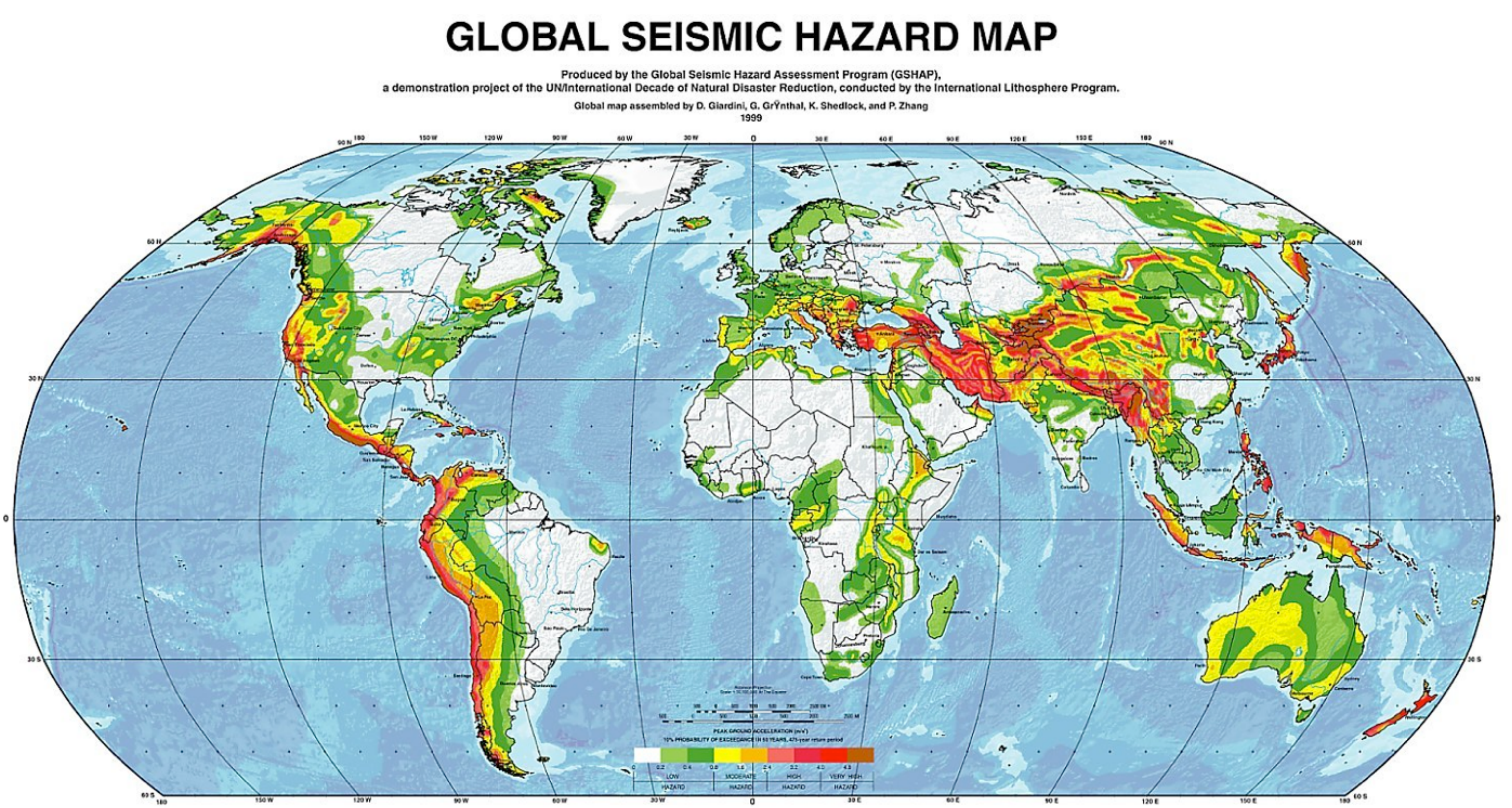
They need stress and fragile rocks,
they are cyclic events that need high force load:
then they do not happen everywhere…

Where?

How much strong?

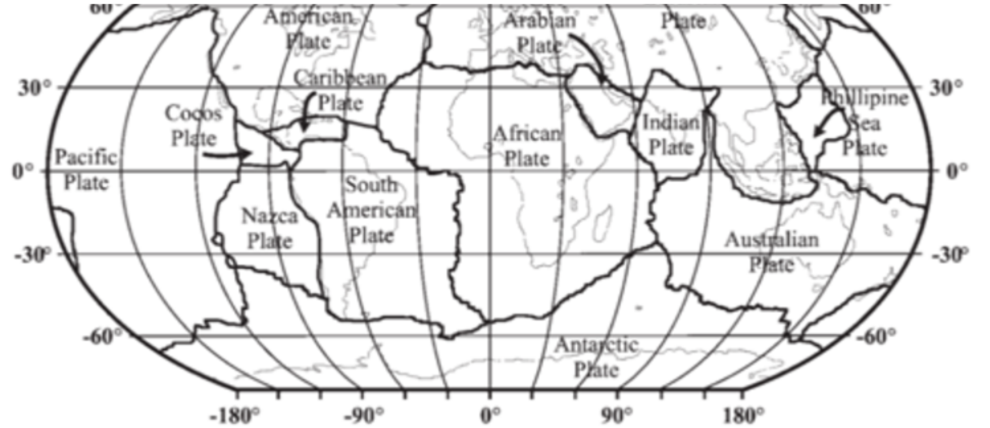
When?

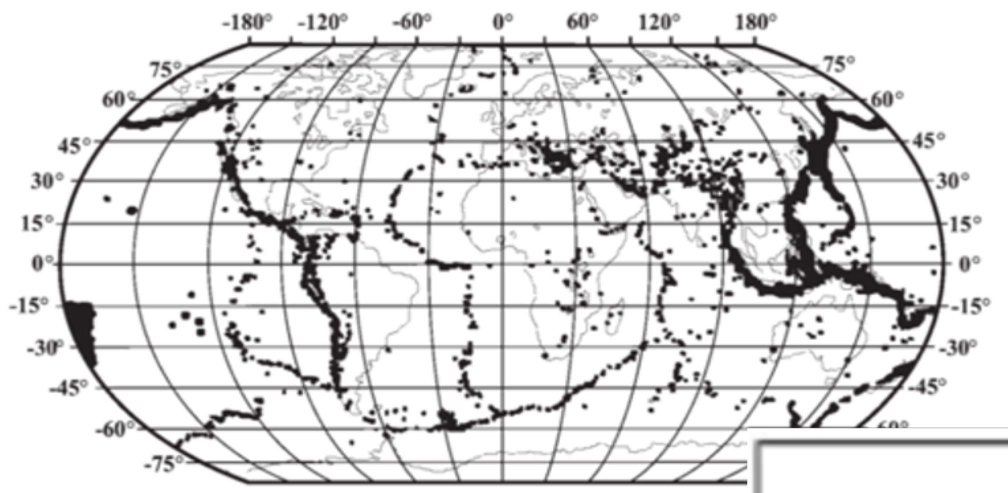
where?



Where we have stress loading

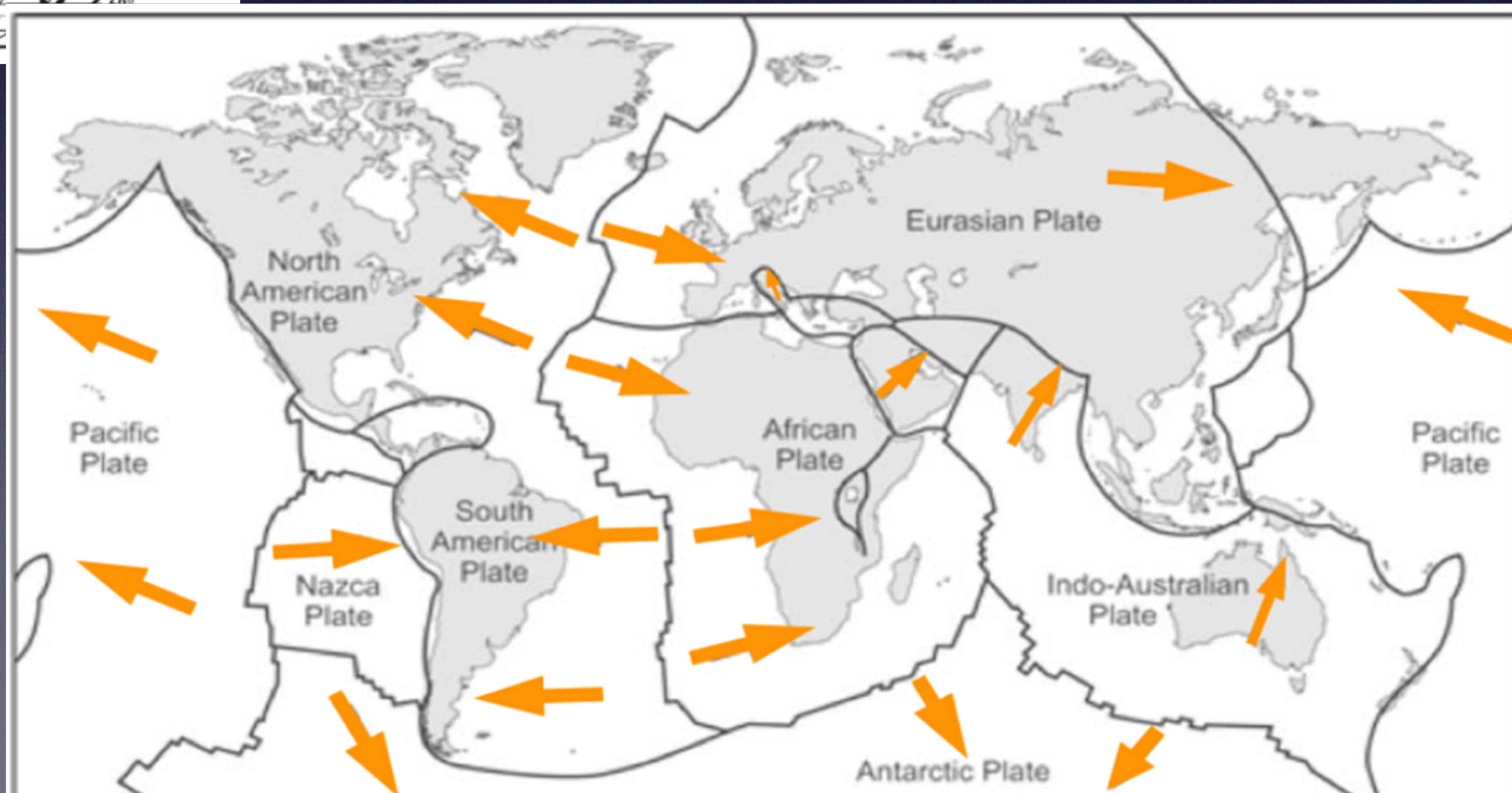
TECTONIC PLATES BOUNDARIES





SEISMIC EVENTS

TECTONIC STRESS



Fonte: S. Danesi, INGV

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log N = a-bM

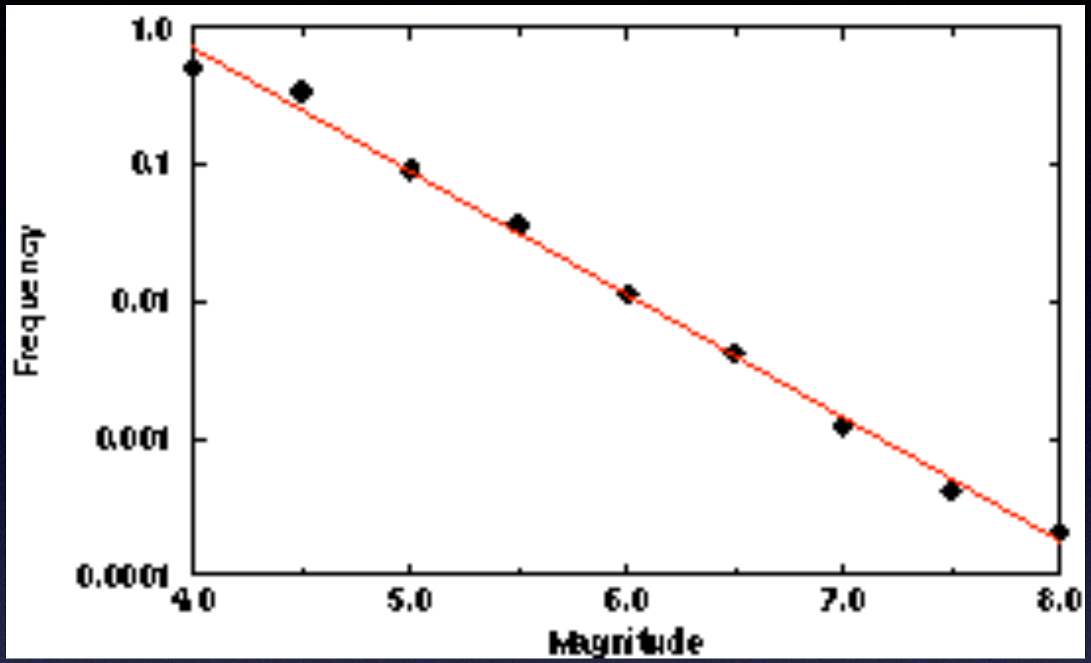
How much strong?

N = earthquakes numbers

M = magnitude

a, b = costants

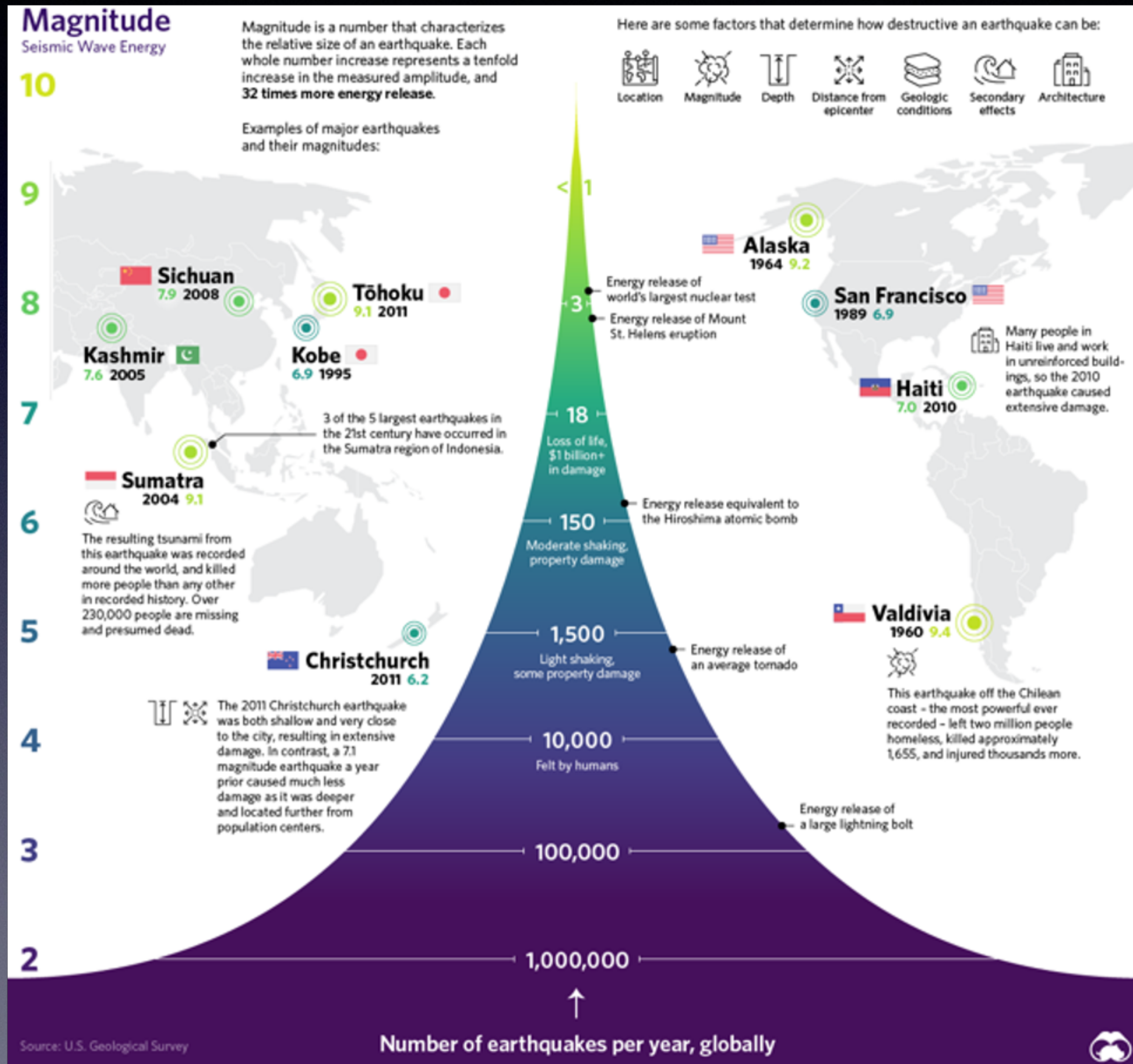
Richter law



Earthquake	Body wave magnitude m_b	Surface wave magnitude M_s	Fault area (km^2) (lengthxwidth)	Average dislocation (m)	Moment (dyn–cm) M_0	Moment Magnitude M_w
Truckee, 1966	5.4	5.9	10x10	0.3	$8.3x10^{24}$	5.9
San Fernando, 1971	6.2	6.6	20x14	1.4	$1.2x10^{26}$	6.7
Loma Prieta, 1989	6.2	7.1	40x15	1.7	$3.0x10^{26}$	6.9
San francisco, 1906		7.8	450x10	4	$5.4x10^{27}$	7.8
Alaska, 1964	6.2	8.4	500x300	7	$5.2x10^{29}$	9.1
Chile, 1960		8.3	800x200	21	$2.4x10^{30}$	9.5

How much strong?

Big events are rare, small ones occur often



How much strong?

The Earthquakes measurements

Intensity (e.g. MCS scale: Mercalli Cancani Sieberg)

It is an empirical measurement of the earthquake effect (XII grades)

Magnitude (e.g. Richter scale)

It is an energy measurement from the recordings amplitude (0-9,5)

Intensity
(e.g. MCS scale: Mercalli Cancani Sieberg)

Qualitative description of the effect

I. Not felt	Not felt by humans but technology is capable of sensing it.
II. Weak	Felt only by a few persons during sleep, especially on upper floors of buildings.
III. Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV. Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V. Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI. Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII. Very Strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII. Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX. Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X. Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI. Extremely Dangerous	Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
XII. Catastrophic	Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

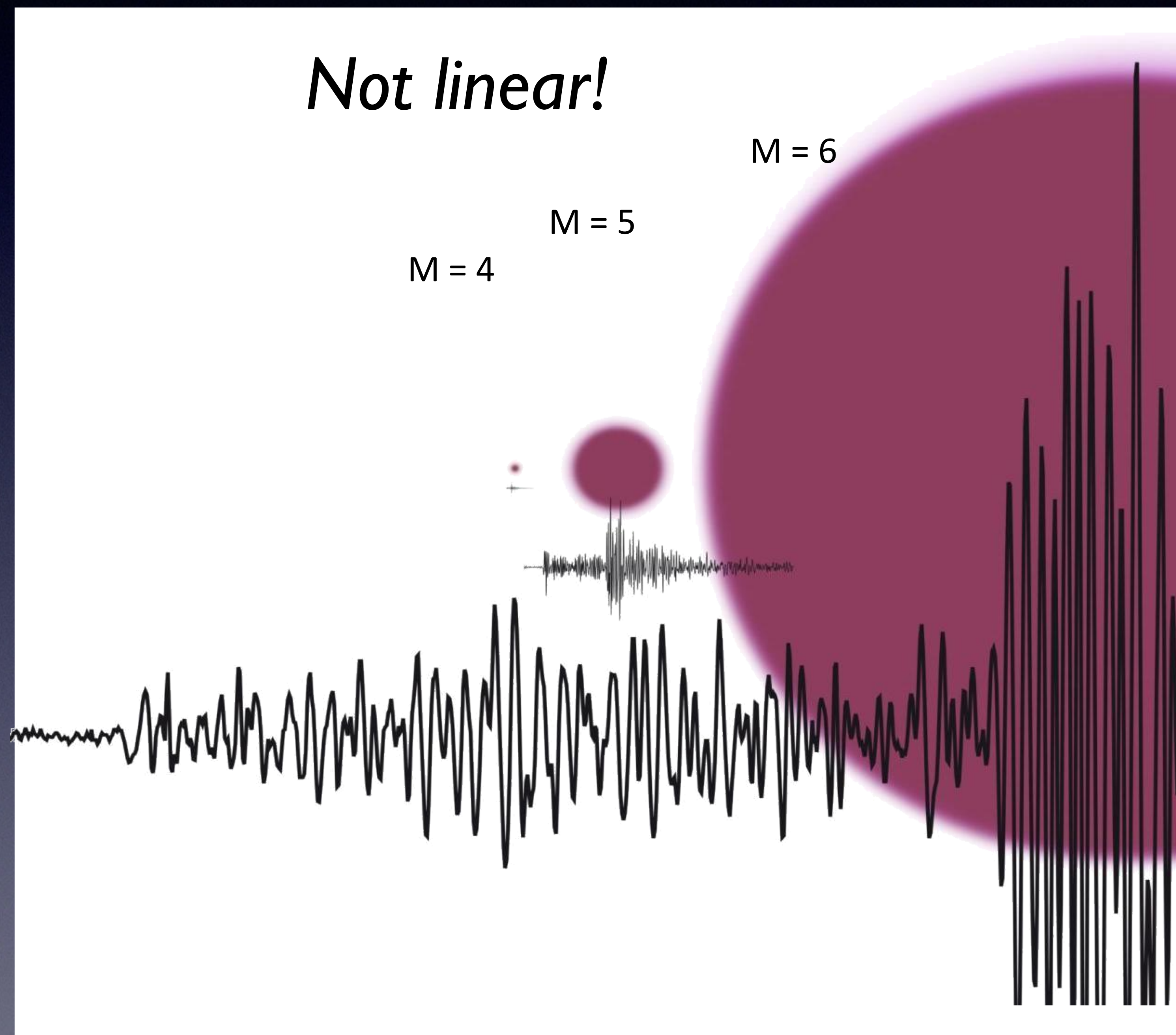
Magnitude

Richter scale

magnitudo	TNT equivalente
0	1 chilogrammo
1	31,6 chilogrammi
1,5	178 chilogrammi
2	1 tonnellata
2,5	5,6 tonnellate
3	31,6 tonnellate
3,5	178 tonnellate
4	1000 tonnellate
4,5	5600 tonnellate
5	31600 tonnellate
5,5	178000 tonnellate
6	1 milione di tonnellate
6,5	5,6 milioni di tonnellate
7	31,6 milioni di tonnellate
7,5	178 milioni di tonnellate
8	1 miliardo di tonnellate
8,5	5,6 miliardi di tonnellate
9	31,6 miliardi di tonnellate
9,5	178 miliardi di tonnellate
10	1000 miliardi di tonnellate

Hiroshima → (5,5)

Instrumental quantitative scale



M6 is about 30 times greater than M5 and about 1000 times greater then M4

Magnitude

Several type of Magnitude

1. local magnitude (ML), aka the "Richter magnitude”
2. Surface-wave magnitude (Ms), based on SW amplitude
3. body-wave magnitude (Mb), based on BW amplitude
4. the moment magnitude (Mw)

All magnitude scales should have the same value for any given earthquake (not trivial for insurances)

Magnitude

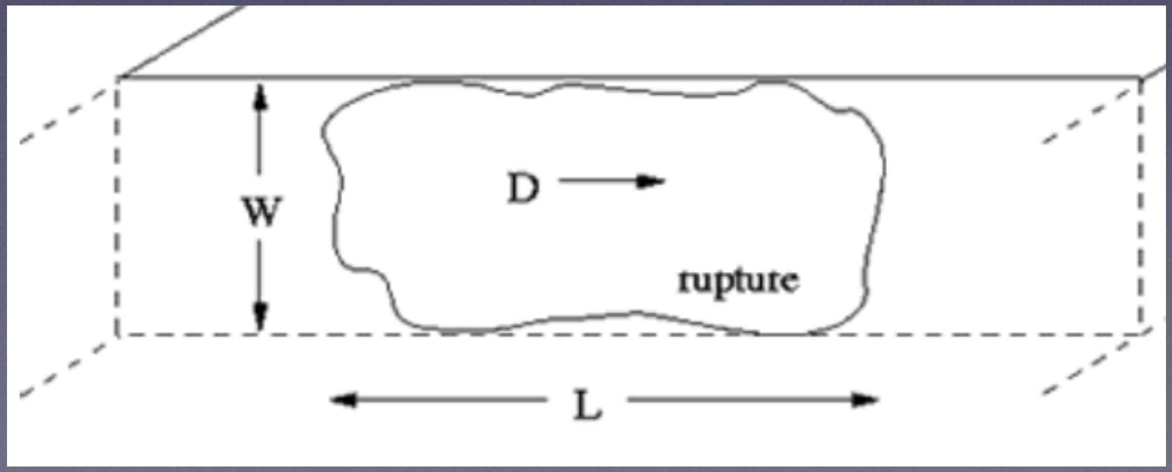
4. the moment magnitude (Mw), base on 'seismic moment'

The seismic moment is a measure of the estimated size of an earthquake based on the area of fault rupture

$$M = \mu A D$$

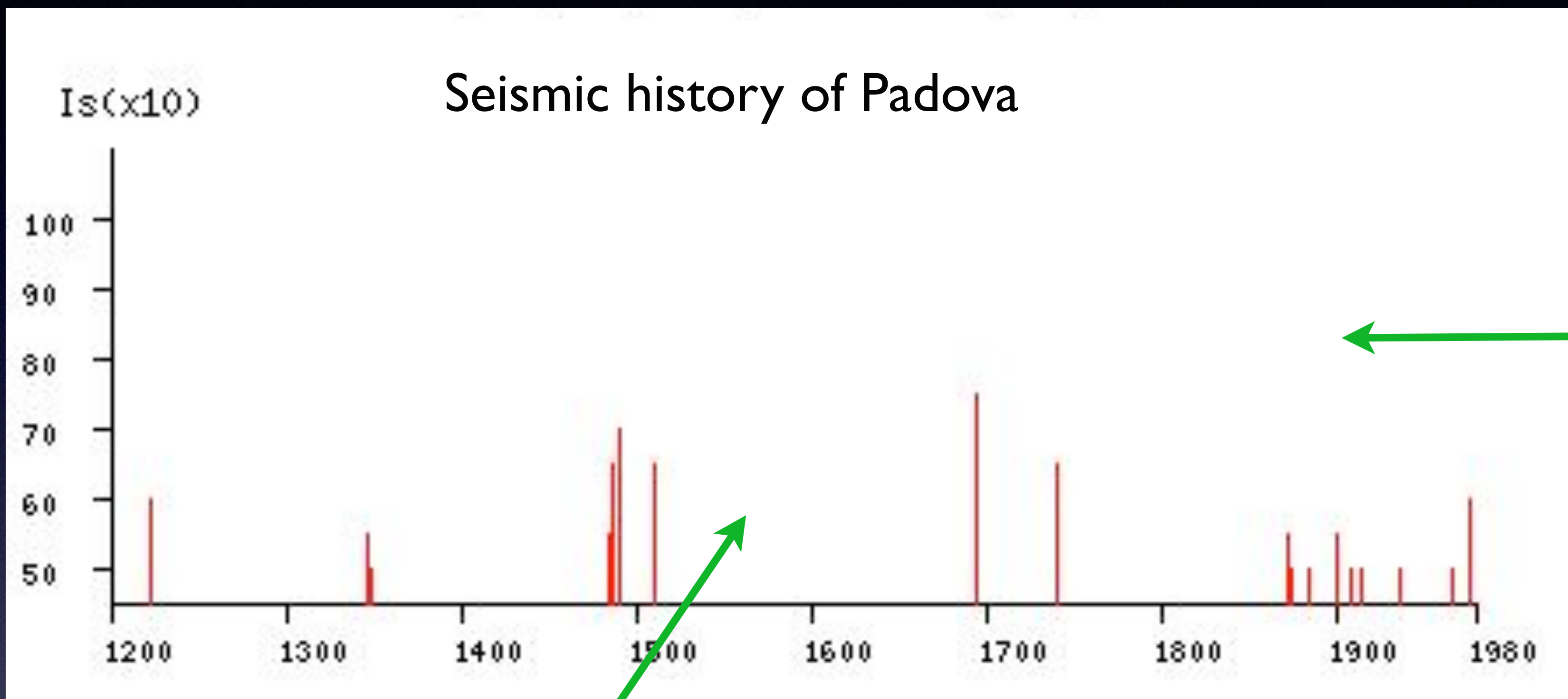
M= seismic Moment
μ = shear modulus (e.g. 32 GPa in crust, 75 GPa in mantle)
A = LW = area of rupture
D = average displacement during rupture

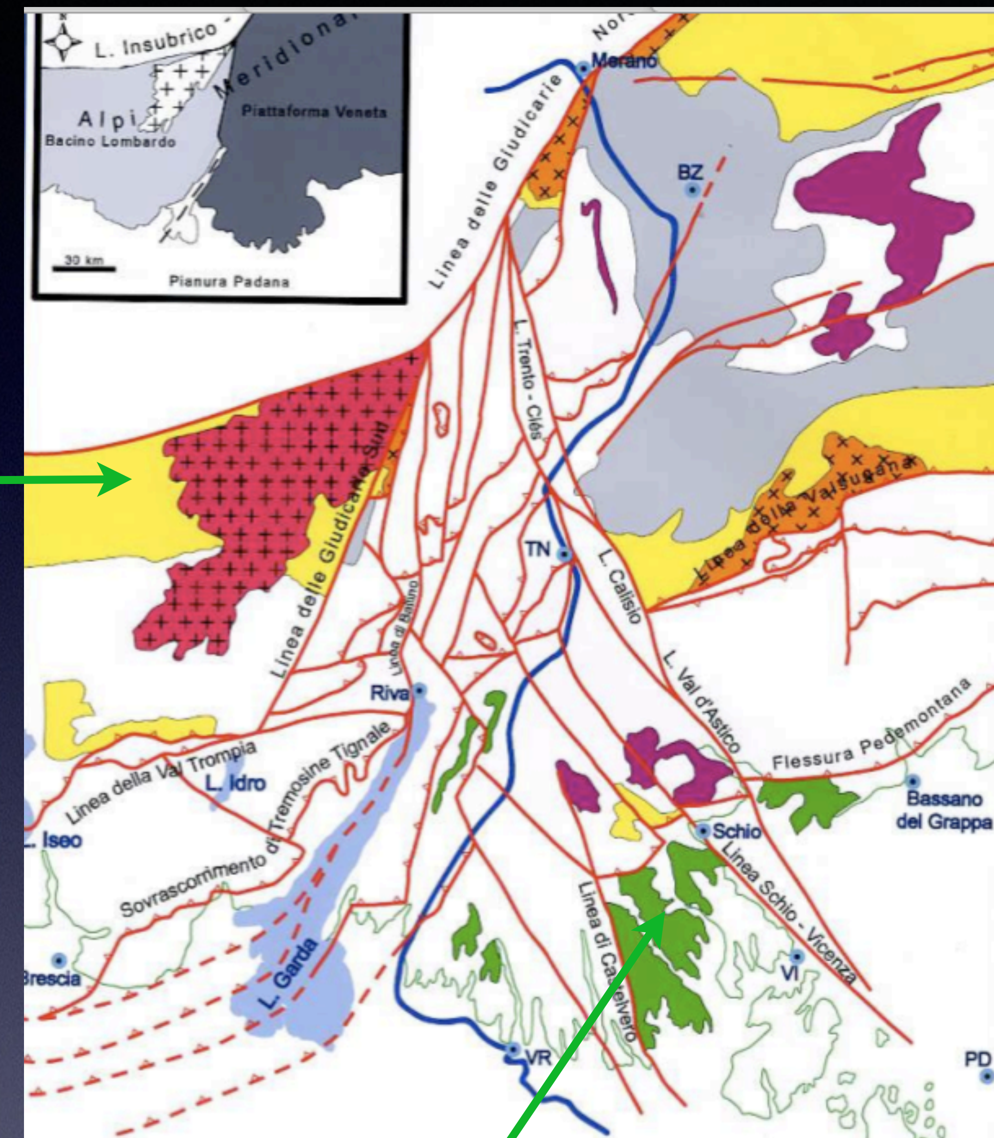
Seismic fault



When?

Not definable…

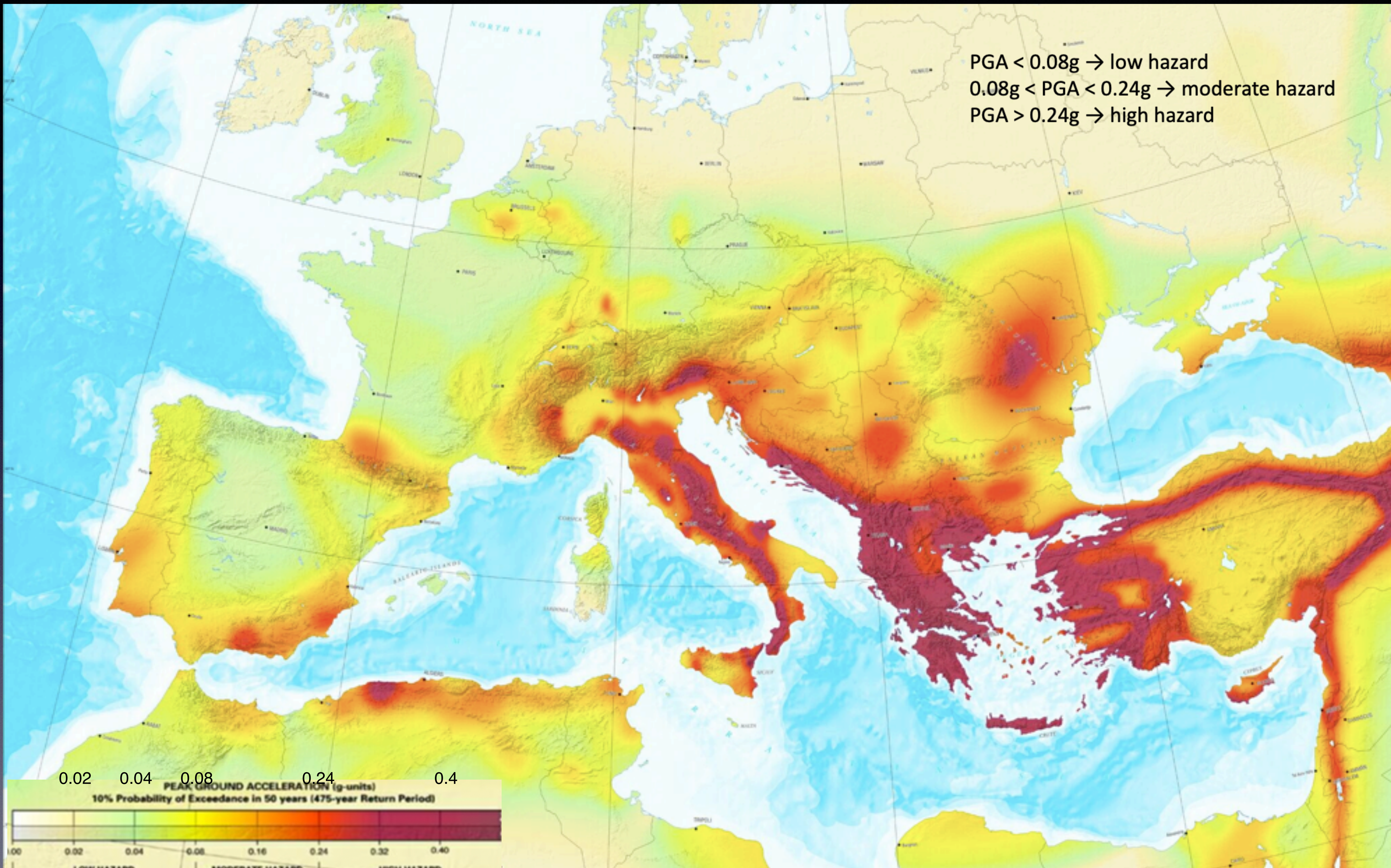




Stress
and strain
are not linear!

Ruptures are not specially defined!

Why to protect…



Seismic hazard of Europe expected ground acceleration Ag (10% 475yrs)

In Europe Strong Hazard or risk?

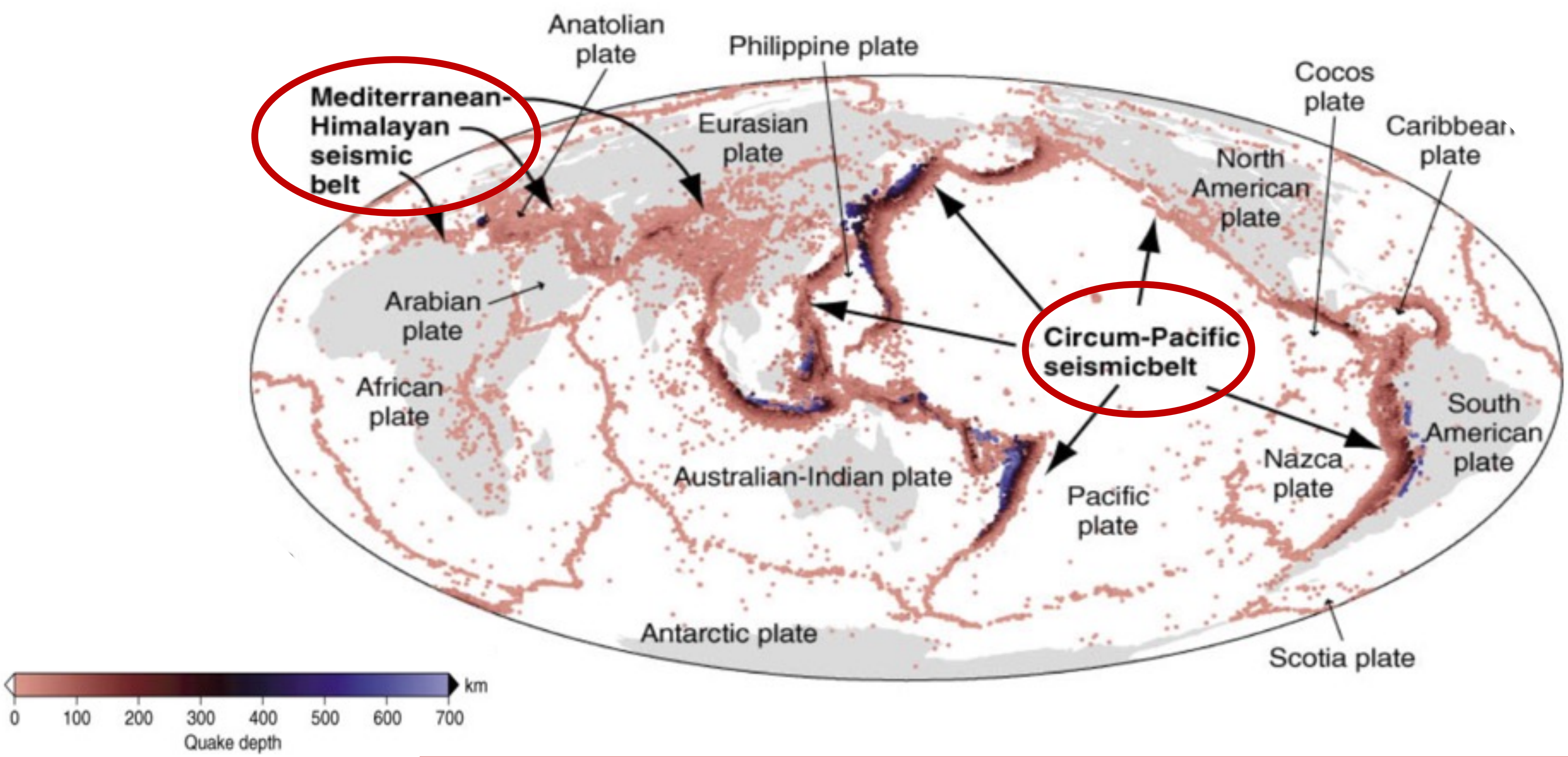
MODULE 4: SEISMIC RISK

1. Seismic Hazard

Main belts (most seismically active):

Circum-Pacific belt (*Ring of Fire*)
80% of all recorded earthquakes originate

Mediterranean-Himalayan belt
responsible of 15% of all earthquakes



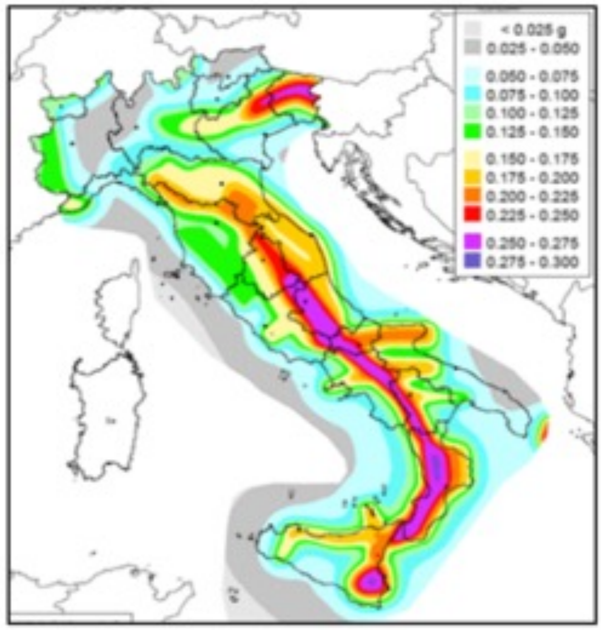
Courtesy Prof.F. Da Porto

SEISMIC RISK

It is a general concept that includes both the probability of the event, and the consequences that the event itself could produce. It is the damage measure that, depending on the type of seismicity, of constructions resistance and anthropization (nature, quality and quantity of assets exposed) can be expected in a given time interval

Risk → $R = H \times V \times E$

Hazard — Vulnerability — Exposure



SEISMIC RISK

DAMAGES !

HAZARD

seismicity: frequency and intensity of earthquakes in a certain area

VULNERABILITY

buildings potential for a given level of damage due to a seismic event of a given intensity

EXPOSURE

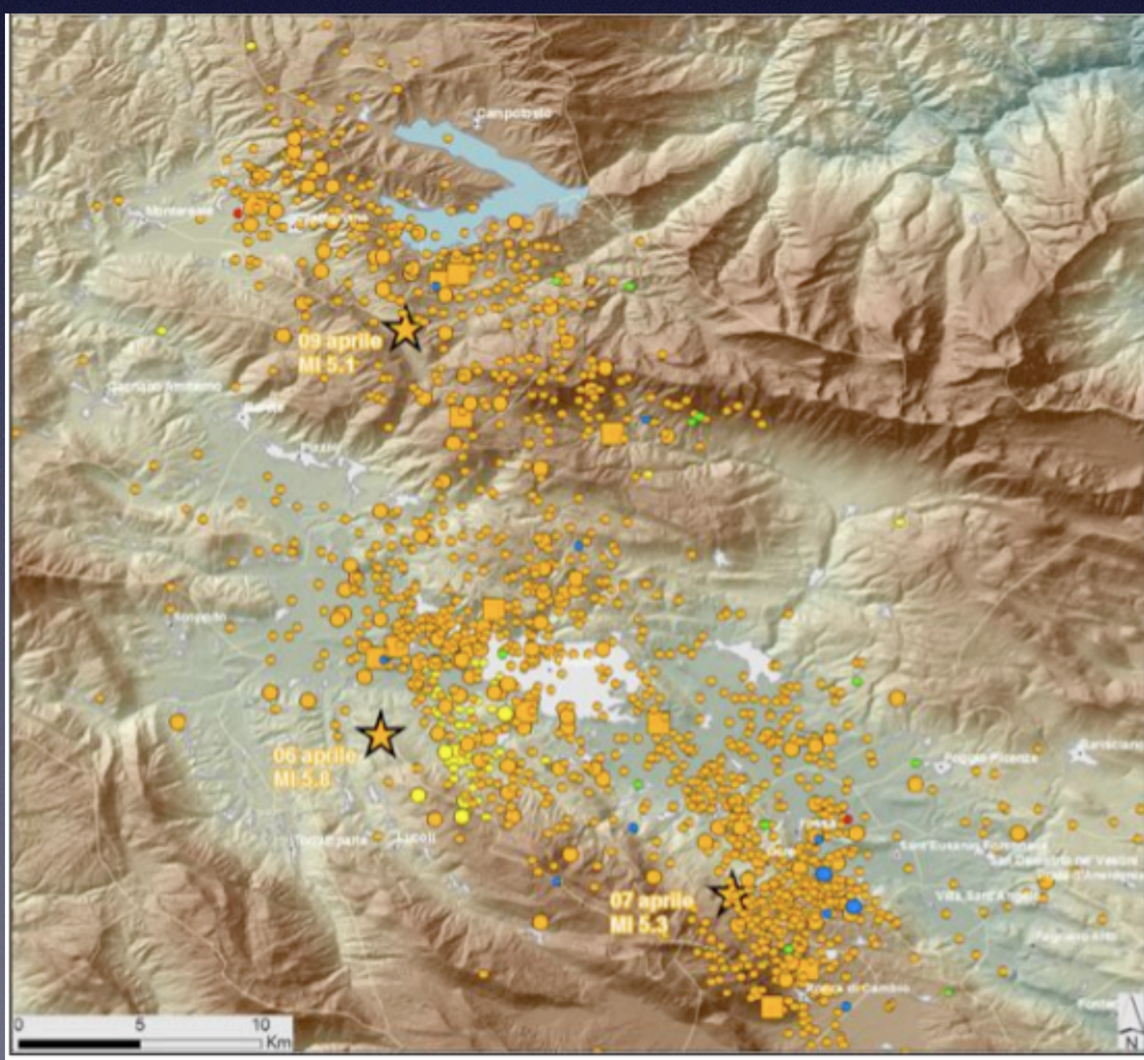
assets that are subjected to the hazard (count of the exposed systems and their value)

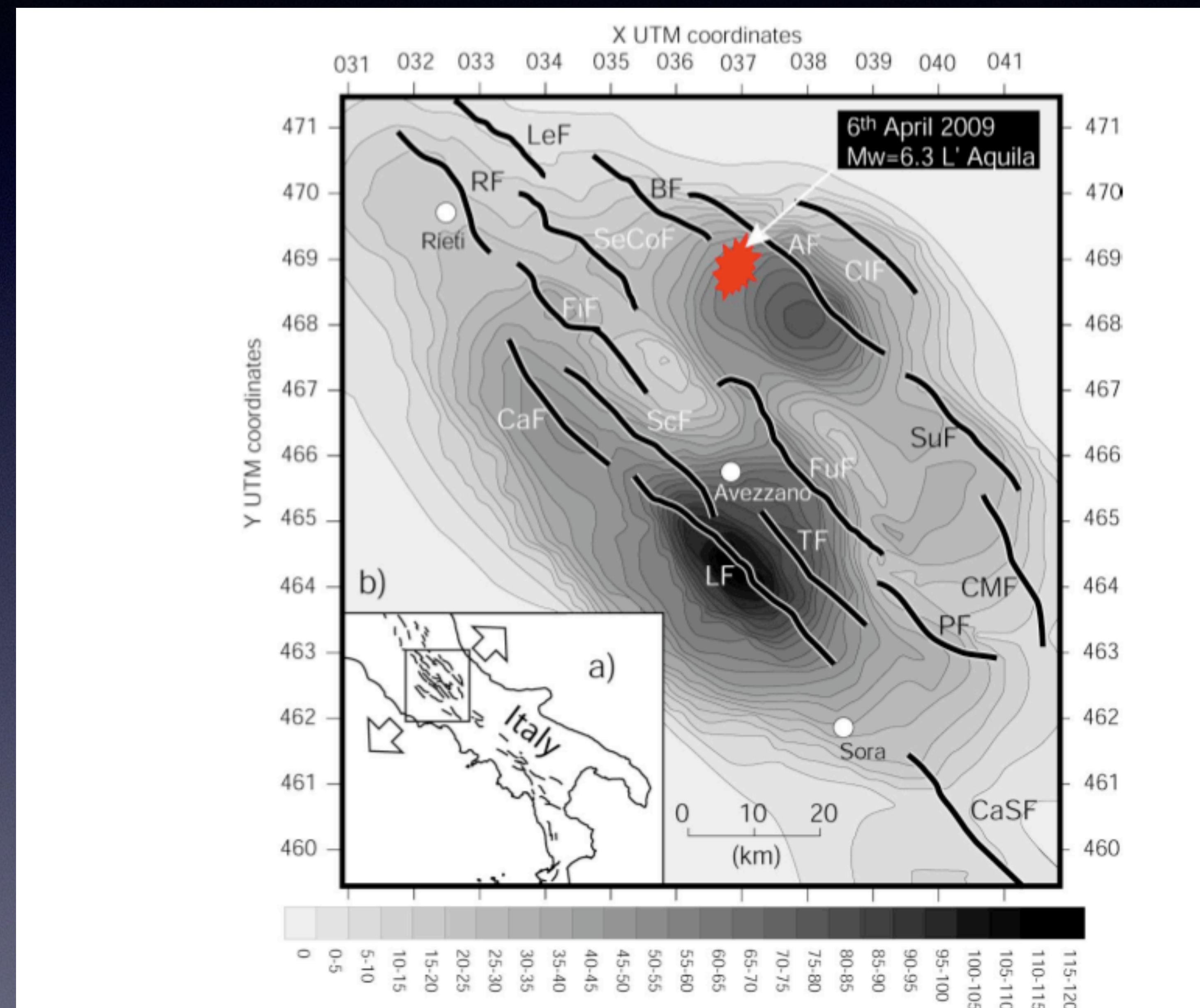
Disclaimer:
Some authors use "hazard" and "exposure" as synonyms, while they use the word "inventory" to indicate the exposed value

Risk = (hazard) x (damage)

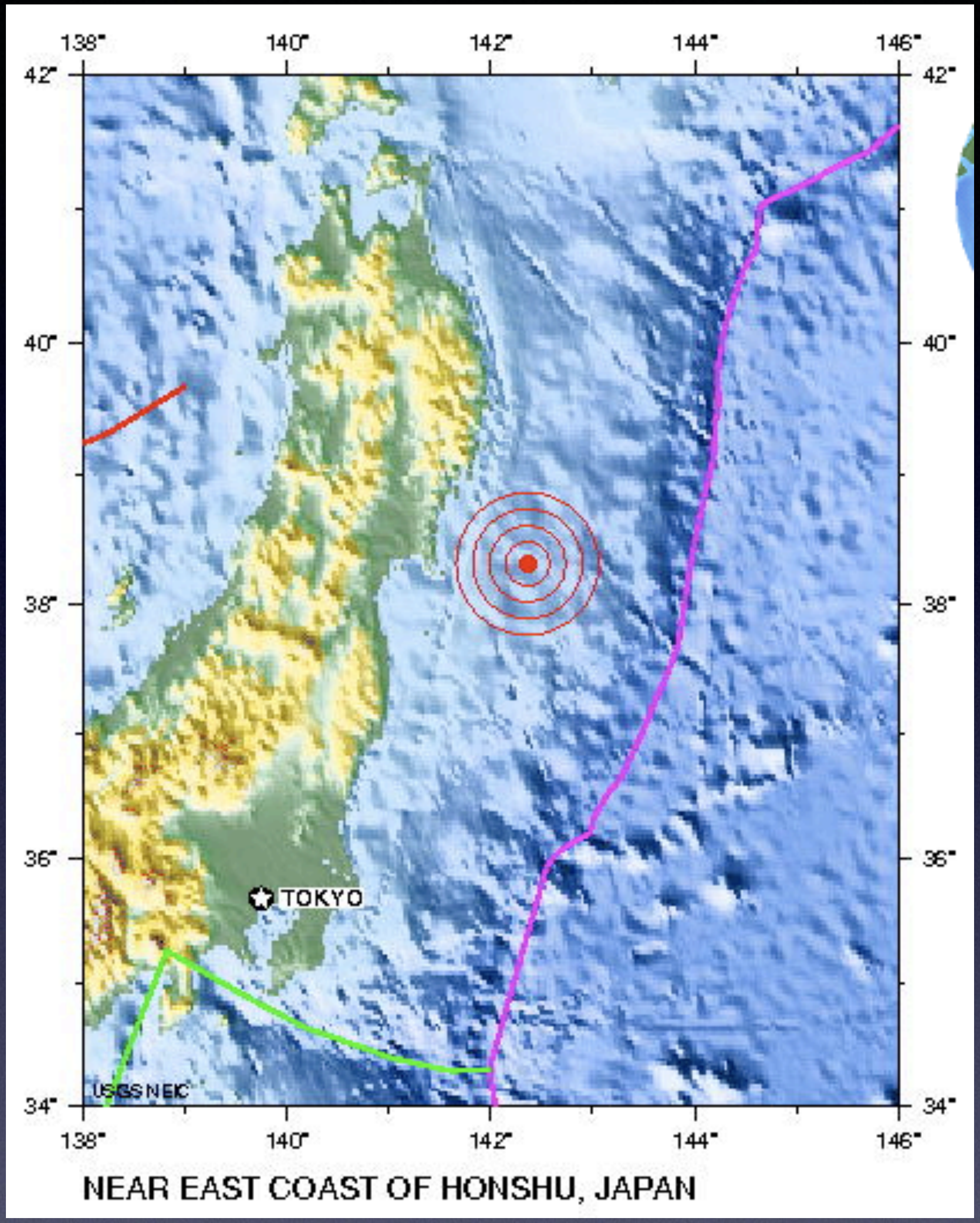
L'Aquila earthquake 6/4/2009

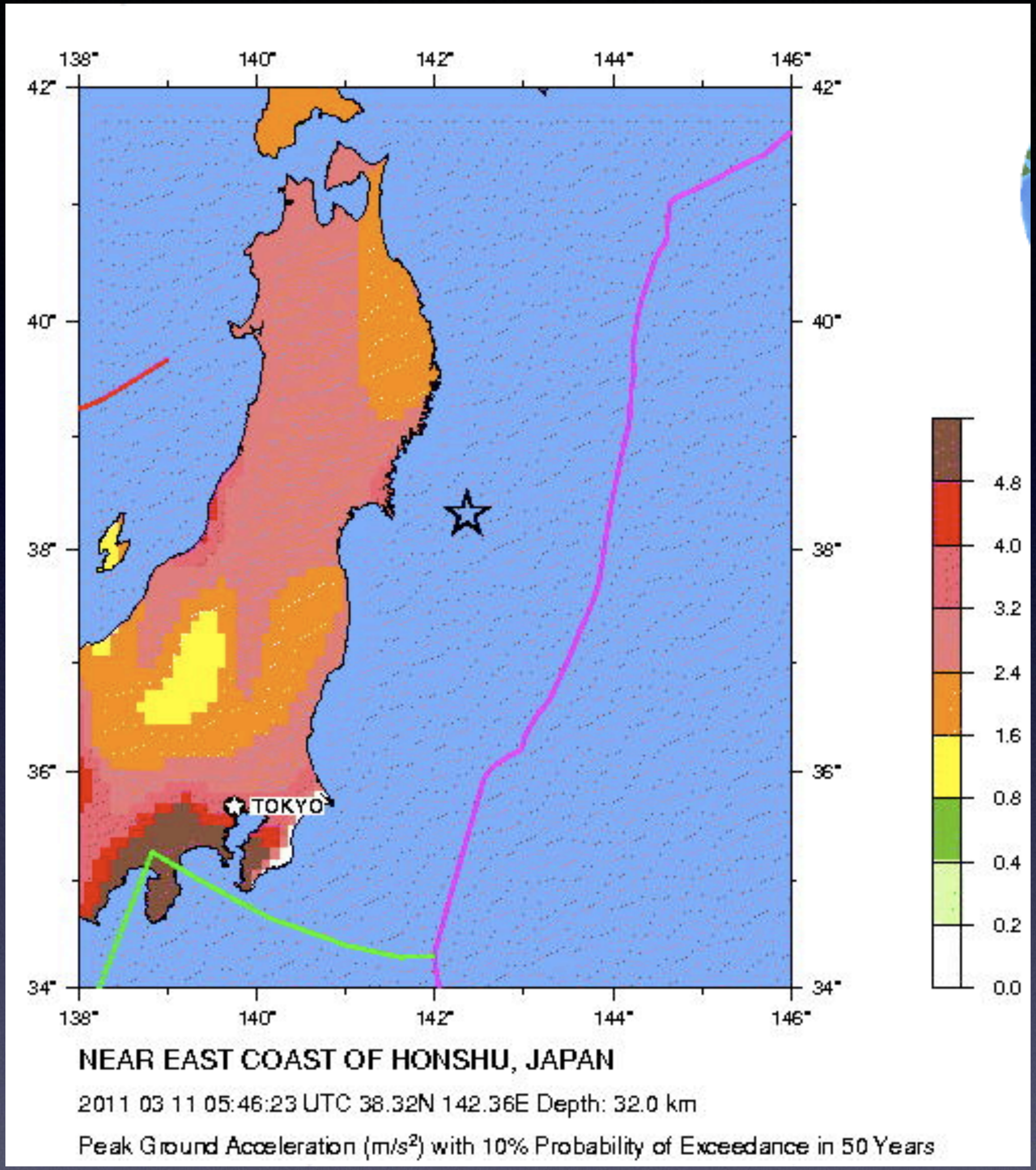
M = 5.8
deaths: 308
15:000 evacuated

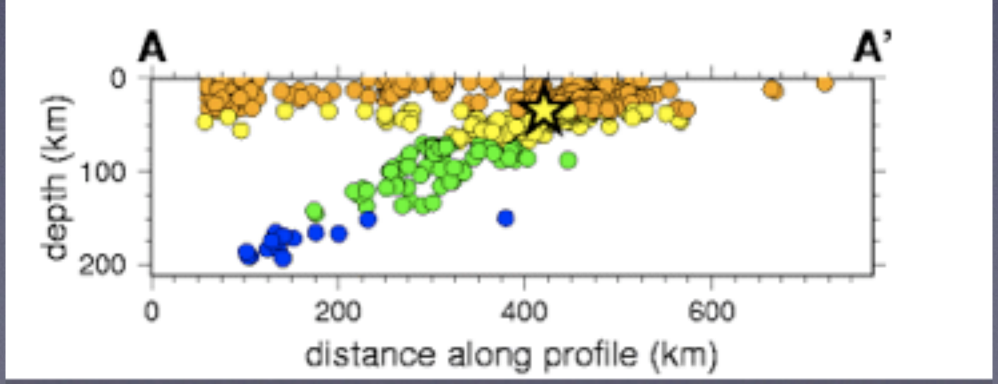




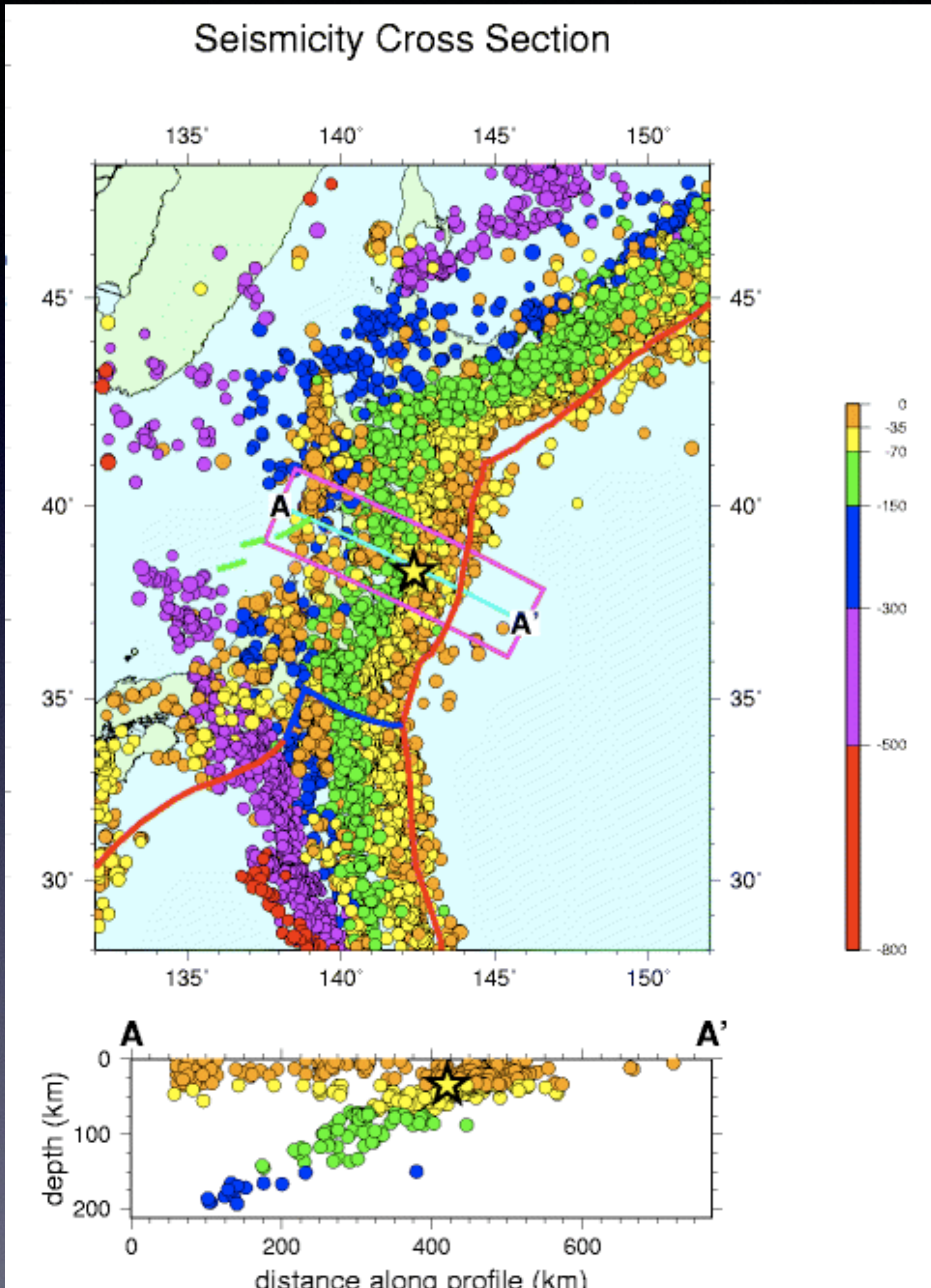
Honshu Earthquake 11/3/2011







Hazard ≠ Risk



Honshu Earthquake

M = 7.2
8 April 2011

deaths: 3

Hazard ≠ Risk

Honshu Earthquake vs L'Aquila earthquake

	Honshu	L'Aquila	Difference
energy	9 X 10e19 J	3 X 10e14 J	ca 10e5 (30.000)
max acceleration	3.0 g	0.31 g	10 E+01
max cosismic displacement	17m	10 cm	10 E+02

How to protect ?

Study the territory

(mainly due by government, with the help of professionals and scientists)

Know the problem

2 needs :

Prevent the problem

Design in a-seismic prospective

(task of building designers)

The seismic hazard

(that is not the risk..)

Output:

Classify seismically a territory:
create map of expected ground acceleration

Input:

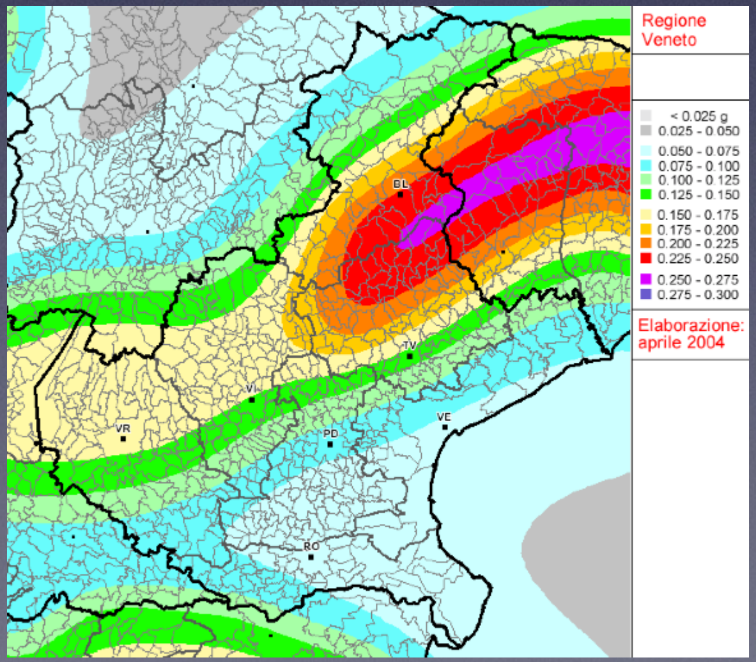
-Historical earthquake catalog (e.g. in Italy V century b.C. - 1970)
-Instrumental recordings (1970-today)

-Knowledge of main geological structure
-Knowledge of geotechnical soil parameters
-Geophysical soil parameters

2 Approaches:

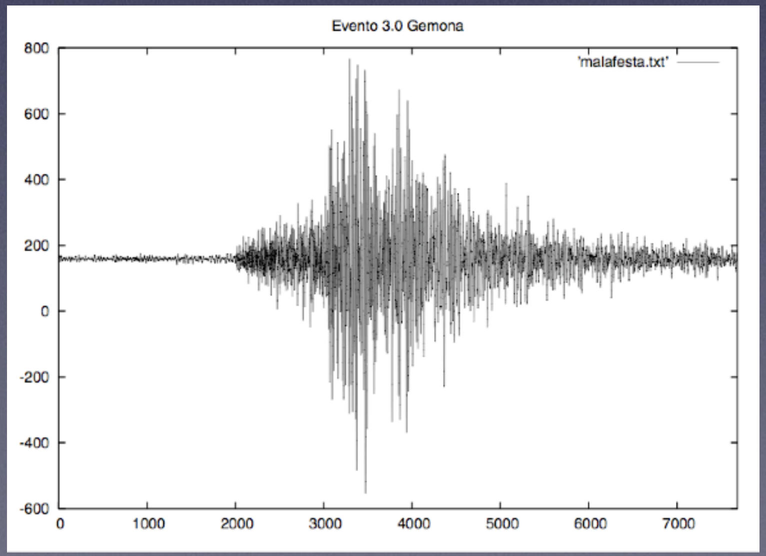
Probabilistic

Probabilistic studies about the occurrence of strong earthquakes based on previous information and geological knowledge (they do not consider the local soil condition !)



Deterministic

Synthetic simulation of ground motion based on:
- source modelling
- propagation of seismic waves through a geological model



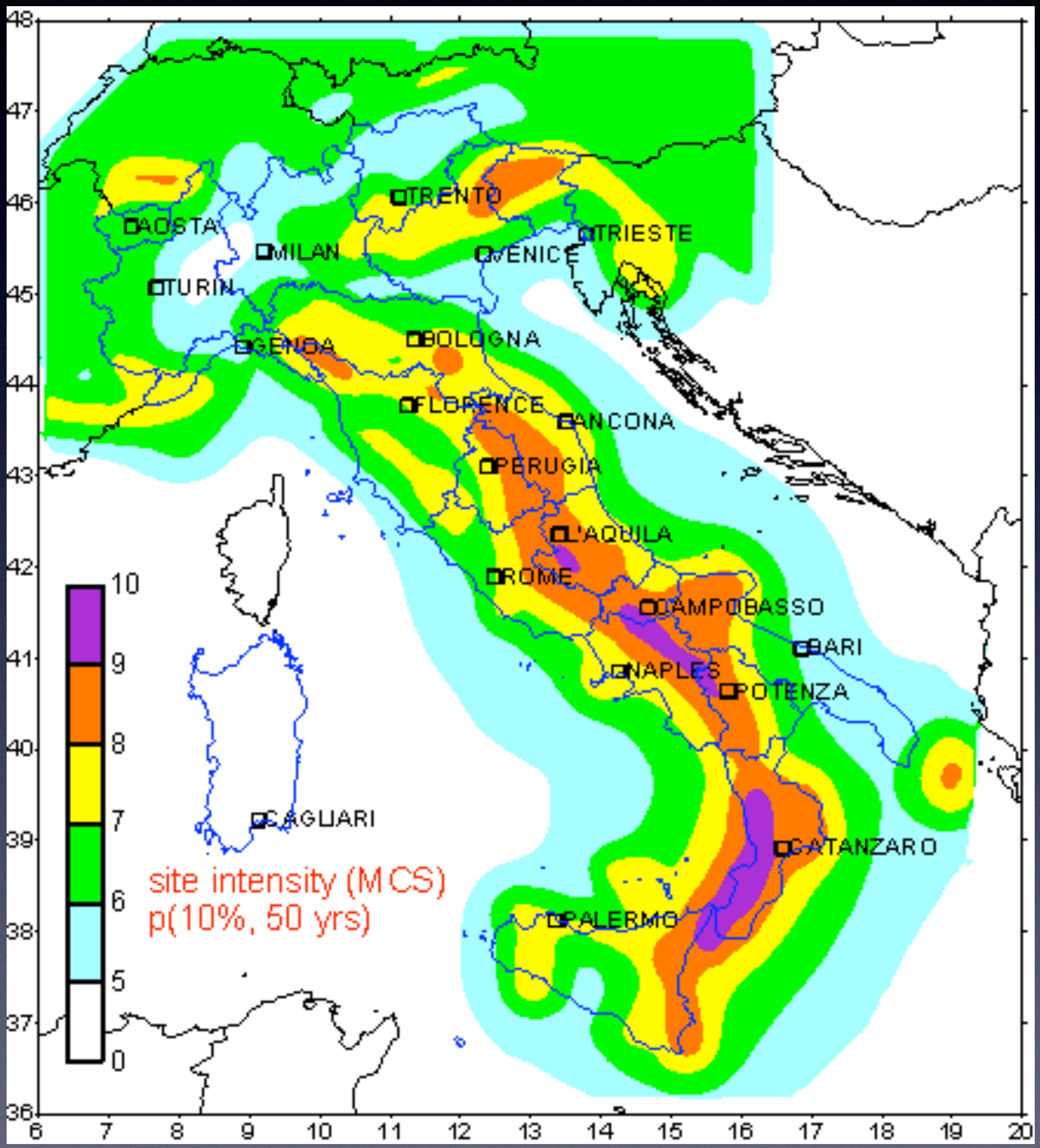
Deterministic is apparently more reliable but we have huge uncertainties on deep model and sources

The government prefer then the probabilistic one, especially where a good historical catalog make statistic robust

but….

what about time-spatial uncertainties ?

Macroseismic Intensity Mercalli scale: Just a ‘picture’ of the past events



Qualitative scale

I Non percepito salvo che in casi particolari; animali inquieti; fronde che stormiscono; porte e lampadari che oscillano.

II Percepito solo da persone sdraiate, soprattutto ai piani alti degli edifici.

III Percepito in casa; la maggioranza però non riconosce il terremoto; tremito simile a quello dovuto al passaggio di un carro leggero; la durata della scossa può essere valutata.

IV Finestre, piatti e porte vibrano; i muri scricchiolano; vibrazione simile a quella dovuta al passaggio di carri pesanti; percepito da molti in casa, da pochi all'esterno.

V Percepito quasi da tutti; molti vengono svegliati; oggetti instabili possono cadere; gli intonaci possono rompersi.

VI Percepito da tutti; mobili pesanti vengono rimossi; i libri cadono ed i quadri si staccano dal muro; le campane suonano; danni occasionali ai camini; danni strutturali minimi.

VII Panico; difficoltà a conservare la posizione eretta; percepito anche dagli automobilisti; danni minimi agli edifici di buona fattura; danni considerevoli agli altri; onde nei laghi e negli stagni.

VIII Disturba la guida di autoveicoli; la struttura degli edifici è interessata fino alle fondamenta, muri di separazione abbattuti; i camini vibrano o cadono; danni lievi solo alle costruzioni antisismiche; i mobili pesanti vengono rovesciati.

IX Panico generale; danni considerevoli anche alle costruzioni antisismiche; caduta di edifici; danni seri ai bacini ed alle tubazioni sotterranee; ampie frature nel terreno.

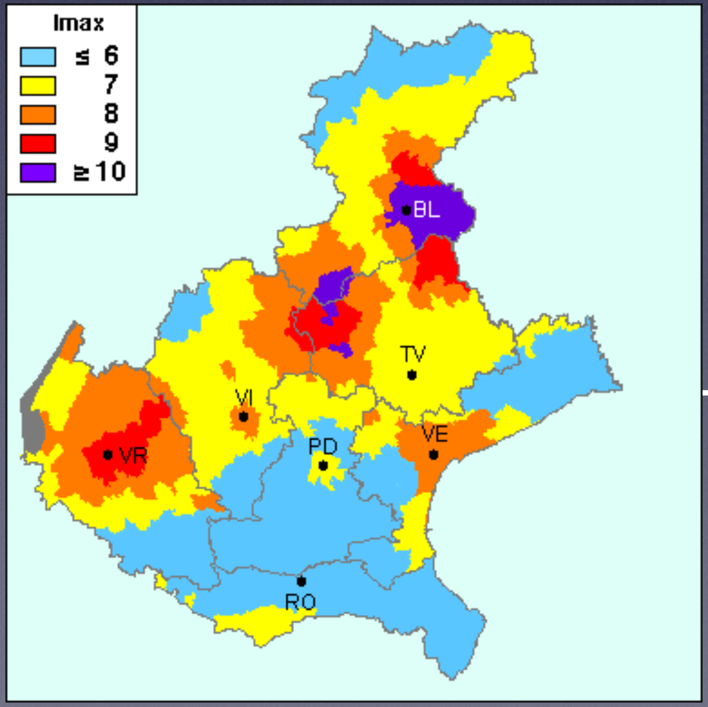
X La maggior parte delle opere in muratura è distrutta, compresi anche gli edifici antisismici; rotaie deformate debolmente; grandi frane.

XI Poche case rimangono in piedi; i ponti distrutti; ampie fessure nel terreno; rotaie fortemente piegate.

XII Distruzione totale; gli oggetti sono addirittura proiettati in ari

The historical catalog has strong uncertainties to answer where and how much strong

Based on :
Historical chronicles, biographies , local documents (the Historical Seismology)



drawback:
Where we have more 'History' there are more earthquakes….

Relation between qualitative and quantitative are generic…

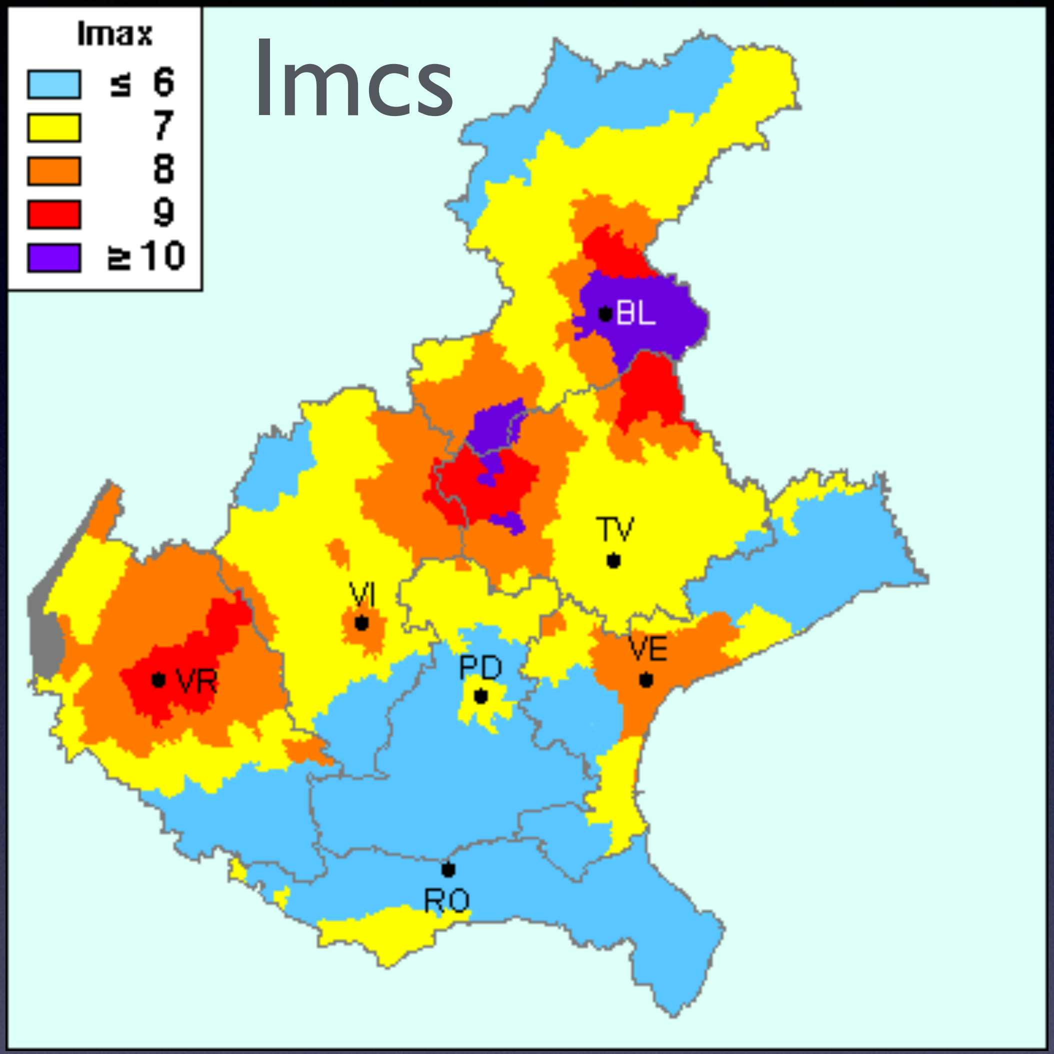
I mcs	PGD (cm)	PGV (cm/s)	DGA (g)
V	0.1-0.5	0.5-1	0.005-0.01
VI	0.5-1.0	1.0-2.0	0.01-0.02
VII	1.0-2.0	2.0-4.0	0.02-0.04
VIII	2.0-3.5	4.0-8.0	0.04-0.08
IX	3.5-7.0	8.0-15.0	0.08-0.15
X	7.0-15.0	15.0-30.0	0.15-0.3
XI	15.0-30.0	30.0-60.0	0.30-0.60

1 grade of Intensity

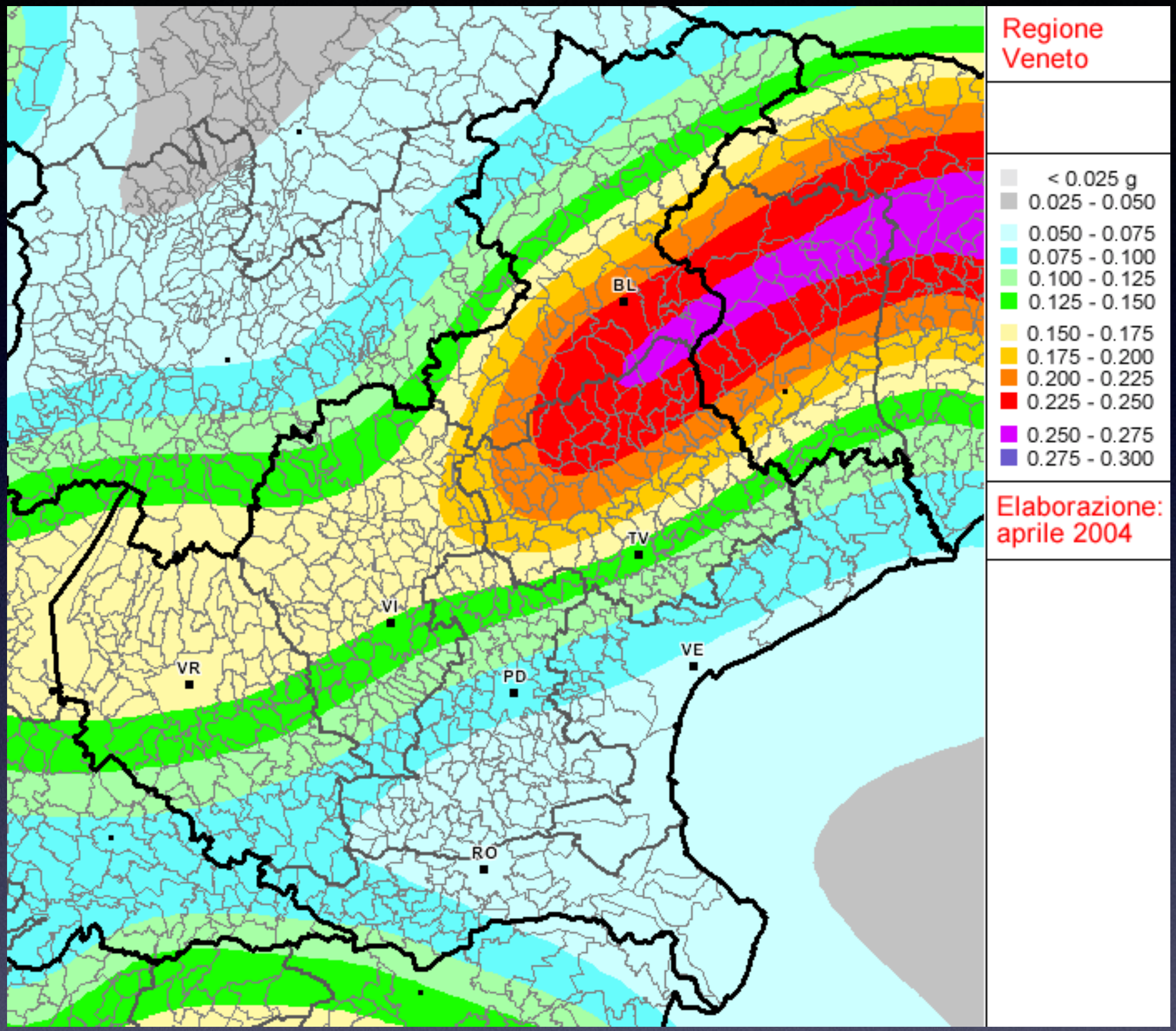
≈ is a double of ground acceleration....

Quality

Quantity

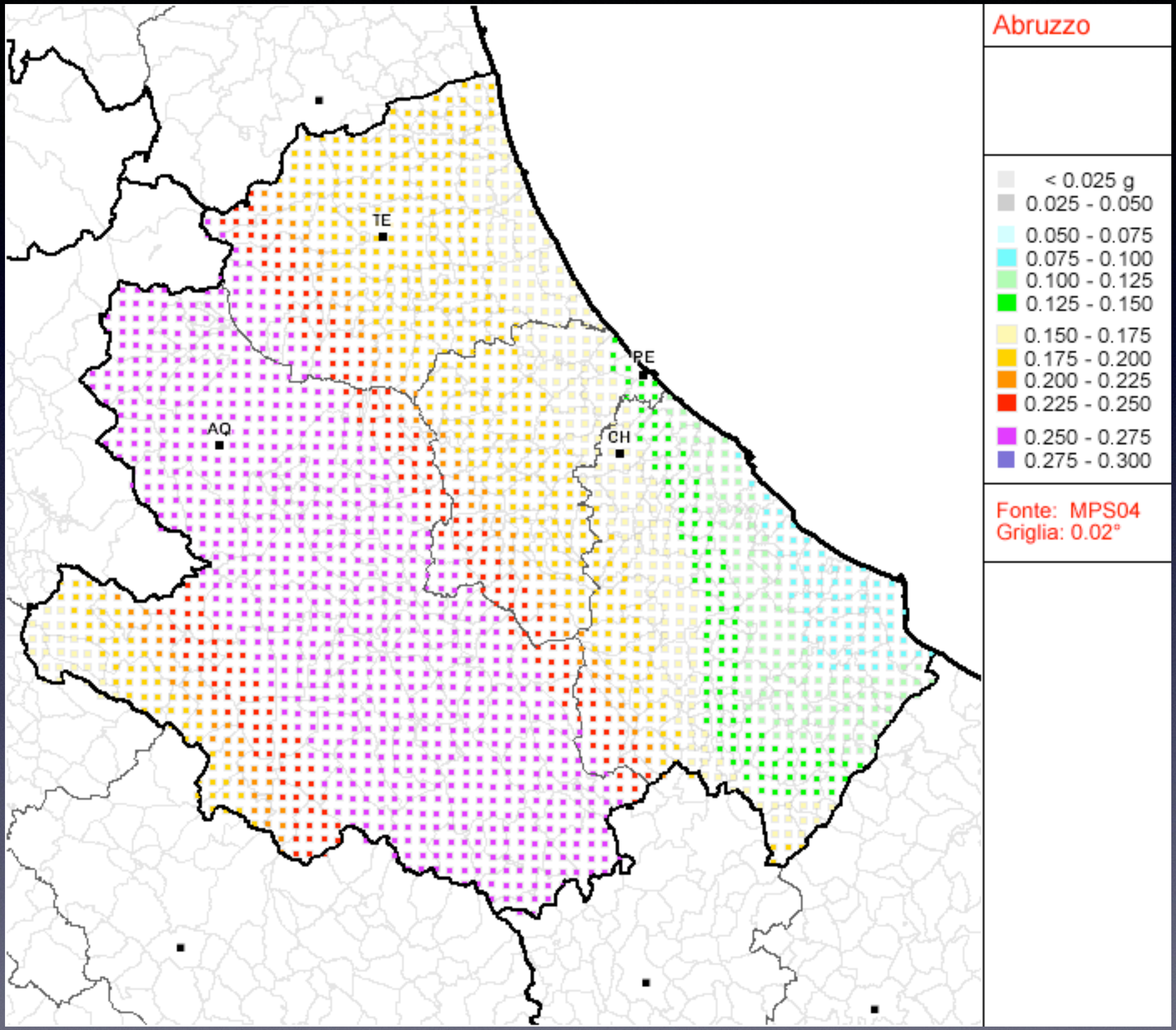


↔



Without considering local site effect !

OPCM 3519, 10 km grid and 10^{-3}g…..??



The Italian norms

Ancona Earthquake ’72....

Legge 2/2/1974 N 64 “Provvedimenti per le costruzioni con particolari prescrizioni per le zone sismiche”

Friuli, Irpinia. Earthquakes ....

DM 11/3/1988 “Norme riguardanti le indagini sui terreni”
DM 4/5/1990 “......dei ponti stradali”
DM 6/1/1996 “...opere in cemento armato e strutture metalliche”
Dm 16/1/1996 ”......carichi e sovraccarichi”
DM 16/1/1996 “costruzioni in zone sismiche”

San Giuliano di Puglia.....

Oridinanza 3274 Norme tecniche per il progetto la valutazione e l'adeguamento sismico degli edifici, modificato sino a 2005
DL 28 maggio 2004 N136 Disposizioni urgenti oer garantire la funzionalità di taluni settori della pubblica amministrazione
DM 14/9/2005 MInistero infrastutture e trasporti 'norme tecniche per le costruzioni'

L’Aquila earthquake 6 april 2009

DM 14/3/2008 MInistero infrastutture e trasporti 'norme tecniche per le costruzioni' Rettificato e imposto

EVOLUTION OF SEISMIC CLASSIFICATION IN ITALY

28/12/1908
Messina
(I_0=XI)

1909

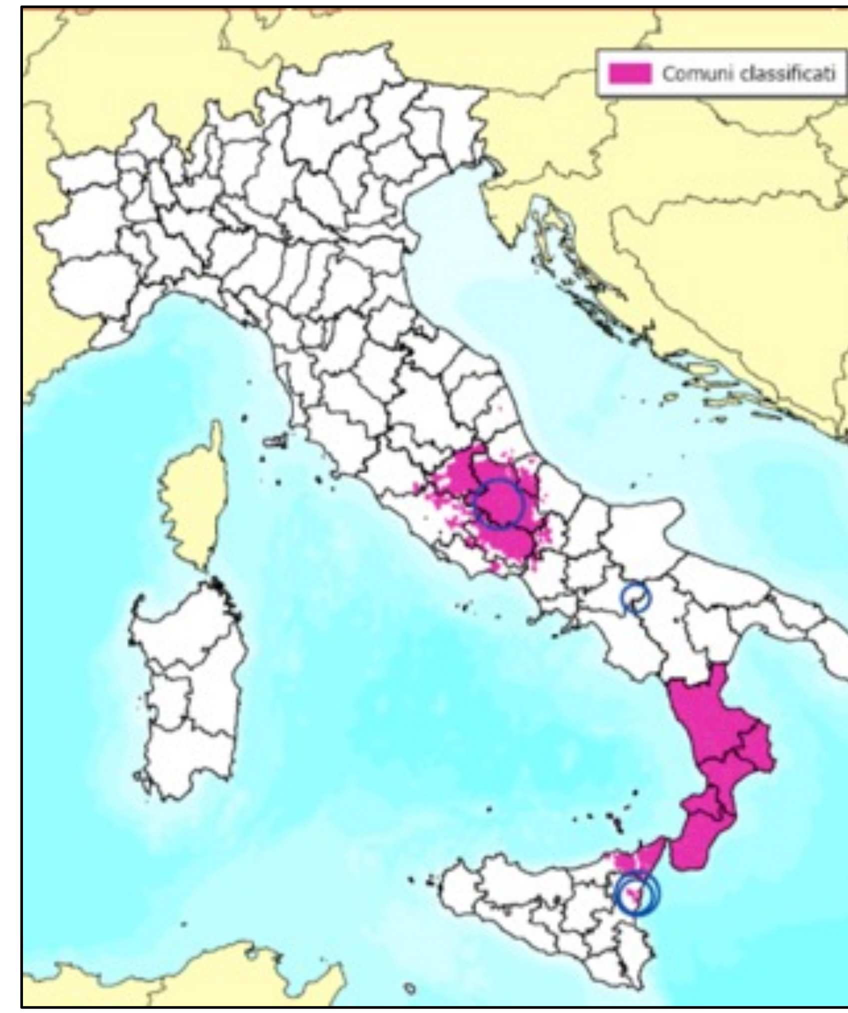
23/03/1910
Etna
(I_0 =IX)

07/06/1910
Irpinia
(I_0 =VIII-IX)

15/10/1911
Etna
(I_0 =X)

13/01/1915
Avezzano
(I_0 =XI)

1915



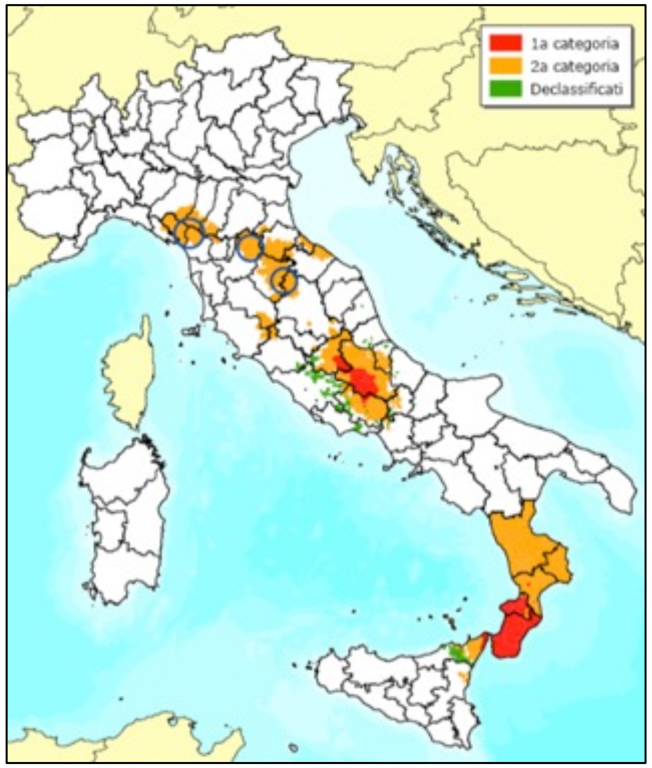
EVOLUTION OF SEISMIC CLASSIFICATION IN ITALY

26/04/1917
Val Tiberina
(I_0=IX)

29/06/1919
Mugello
(I_0=IX)

07/09/1920
Garfagnana
(I_0=IX-X)

1927



27/03/1928
Friuli
(I_0=VIII-IX)

23/07/1930
Irpinia
(I_0=X)

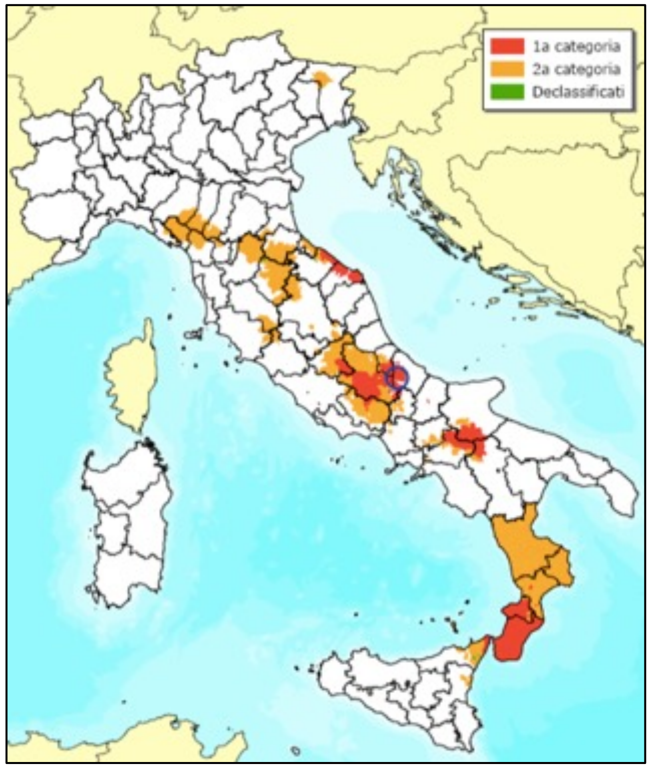
1930

EVOLUTION OF SEISMIC CLASSIFICATION IN ITALY

30/10/1930
Marche
(I_0 =IX)

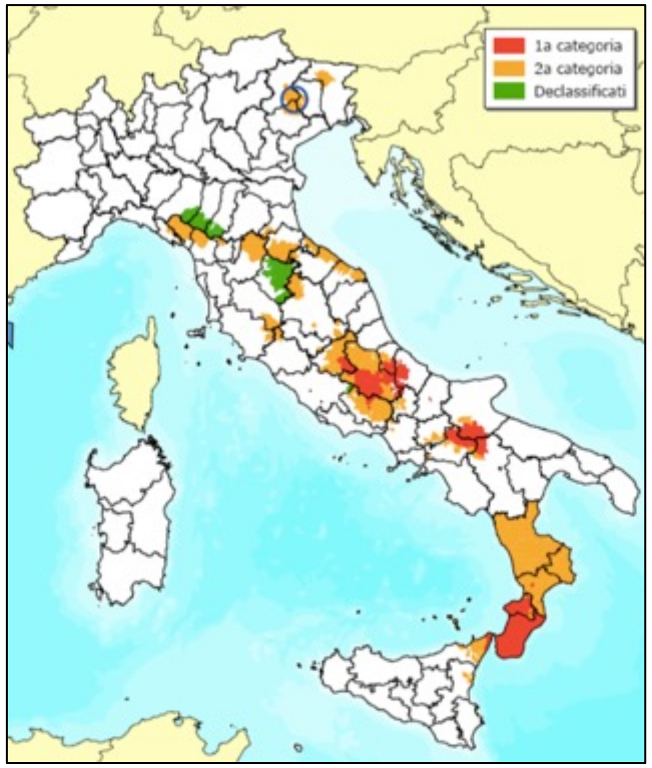
26/09/1933
Maiella
(I_0 =VIII-IX)

1935



18/10/1936
Pieve d'Alpago
(I_0 =IX)

1937

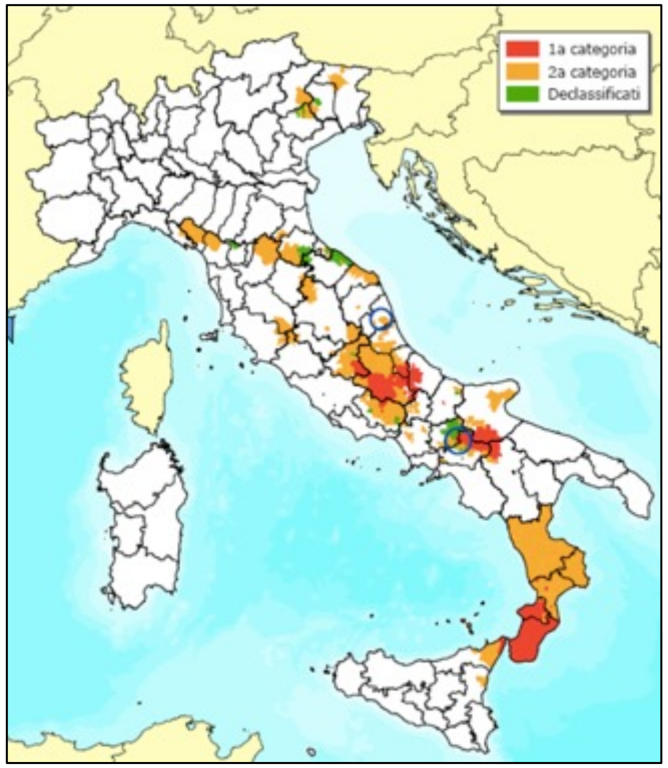


EVOLUTION OF SEISMIC CLASSIFICATION IN ITALY

03/10/1943
Offida
(I_0 =VIII-IX)

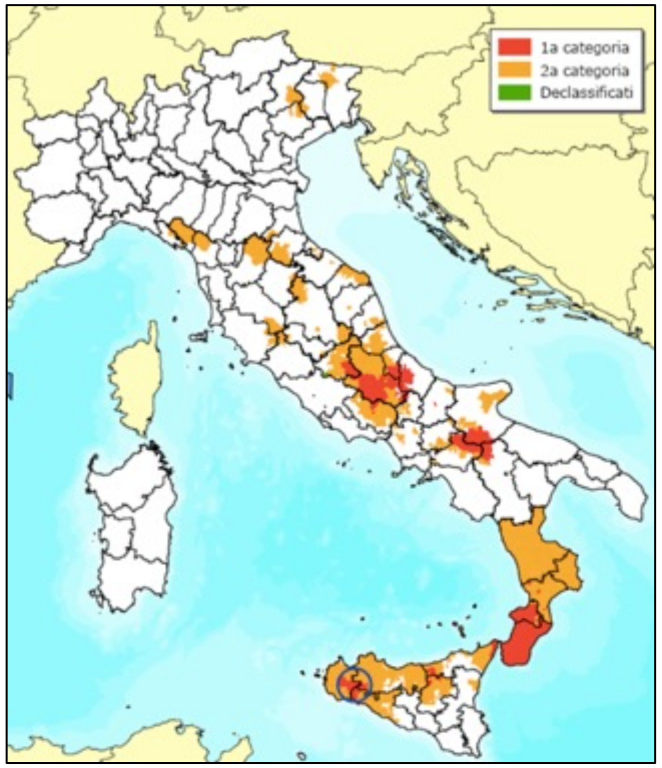
21/08/1962
Irpinia
(I_0 =IX)

1962



15/01/1968
Belice
(I_0 =X)

1975



Courtesy Prof.F. Da Porto

EVOLUTION OF SEISMIC CLASSIFICATION IN ITALY

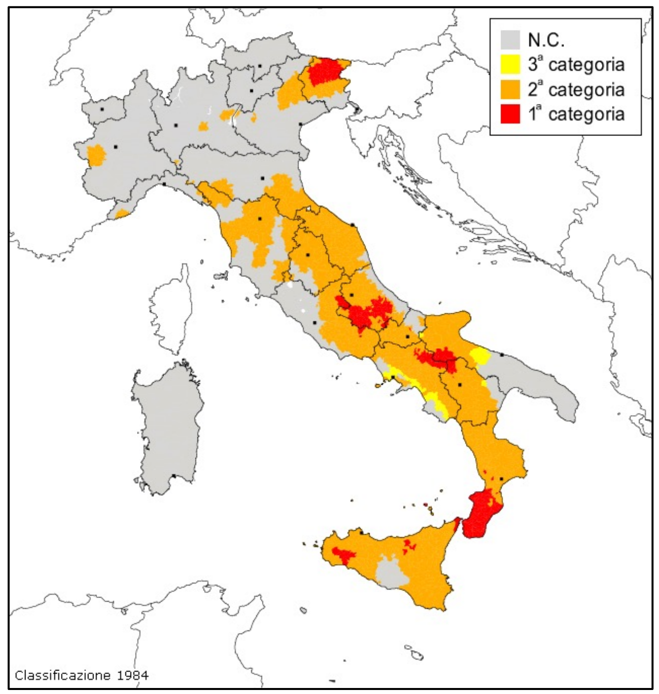
06/05/1976
Friuli
(I_0 =IX-X)

15/04/1978
Patti
(I_0 =IX)

19/09/1979
Valnerina
(I_0 =VIII-IX)

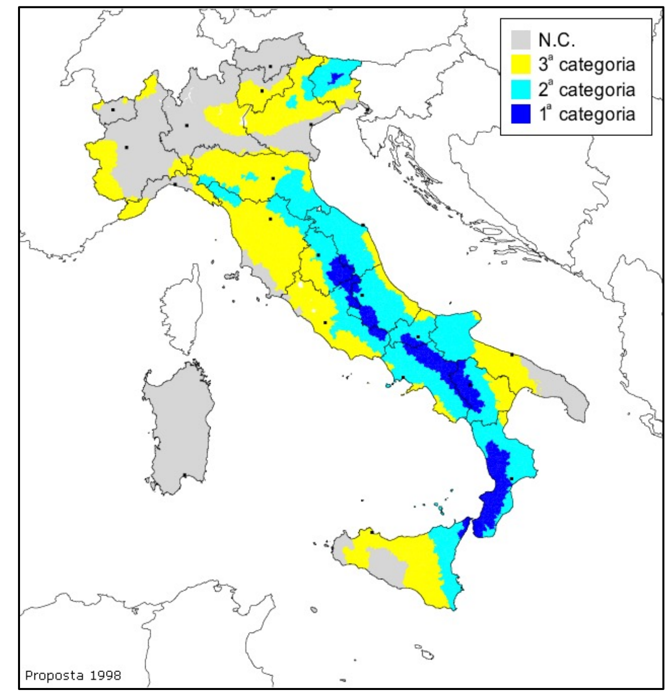
23/11/1980
Irpinia
(I_0 =X)

1984



26/09/1993
Umbria-Marche
(I_0 =VIII-IX)

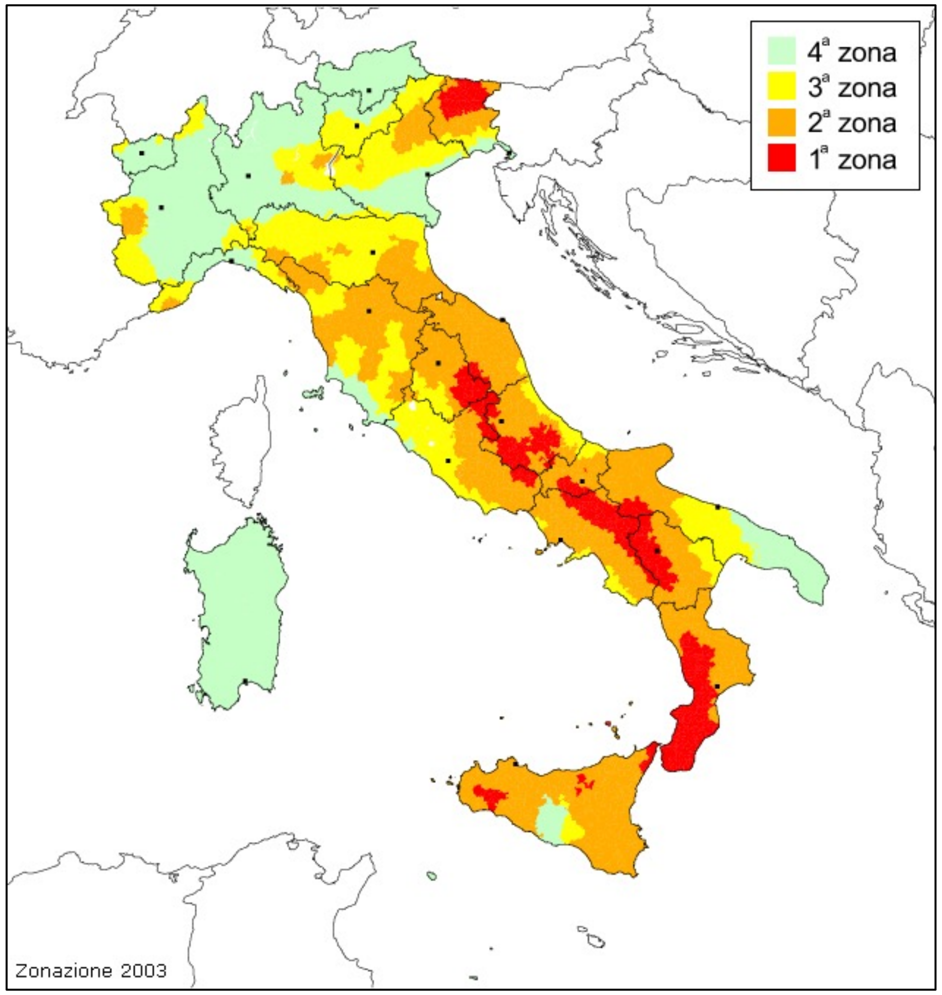
1998



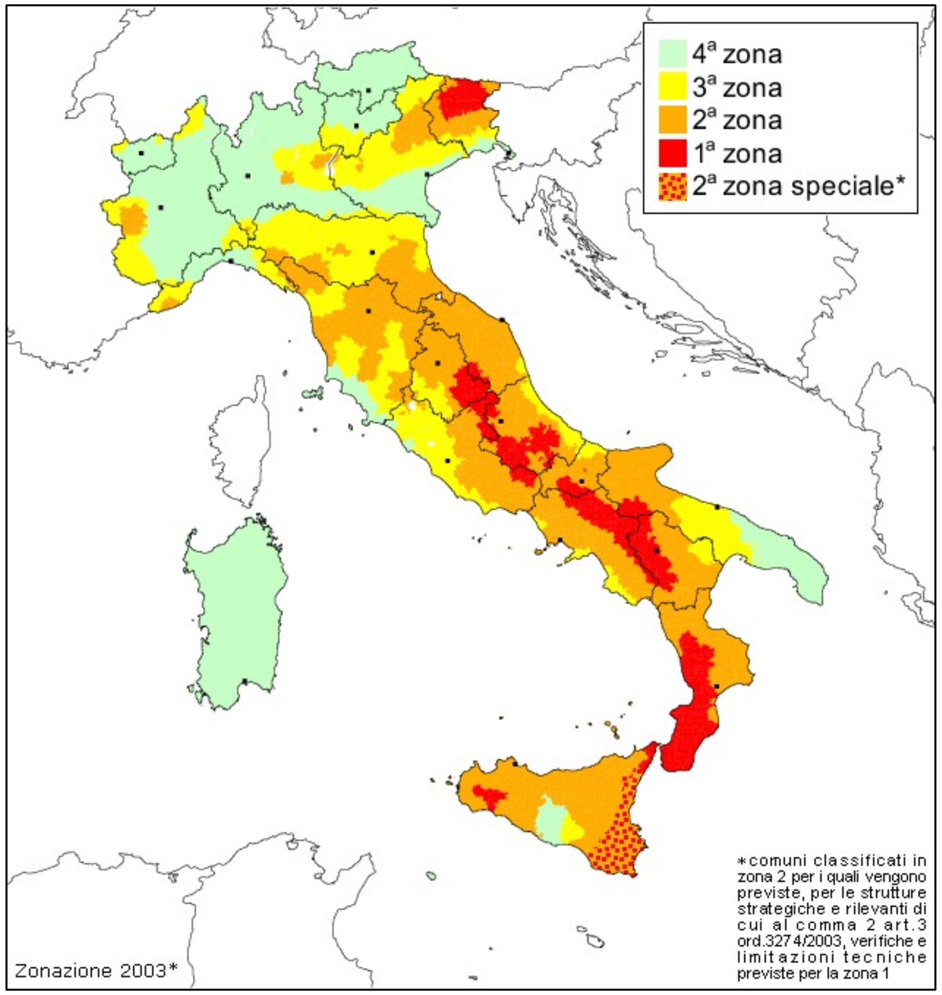
Afterwards the working group (SSN-GNDT-INGV) works on a new proposal of seismic classification, based not only on historical catalogues but also on the knowledge of seismogenetic zones, occurrence models and attenuation relationships. The updating occurred with *Ordinanza PCM n. 3274 del 26 marzo 2003*, which changed the seismic categories into zones, characterized by a nominal value of PGA, and eliminated the non- classified zones.

EVOLUTION OF SEISMIC CLASSIFICATION IN ITALY

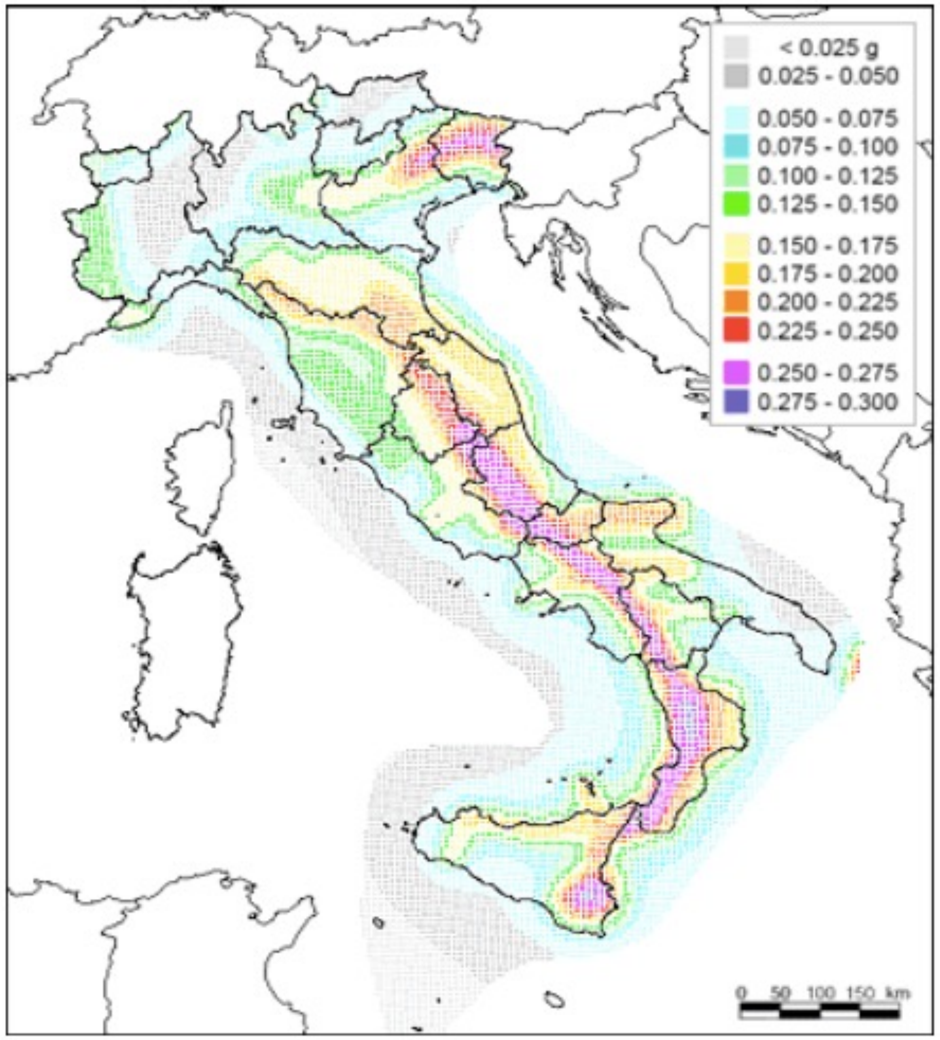
2003

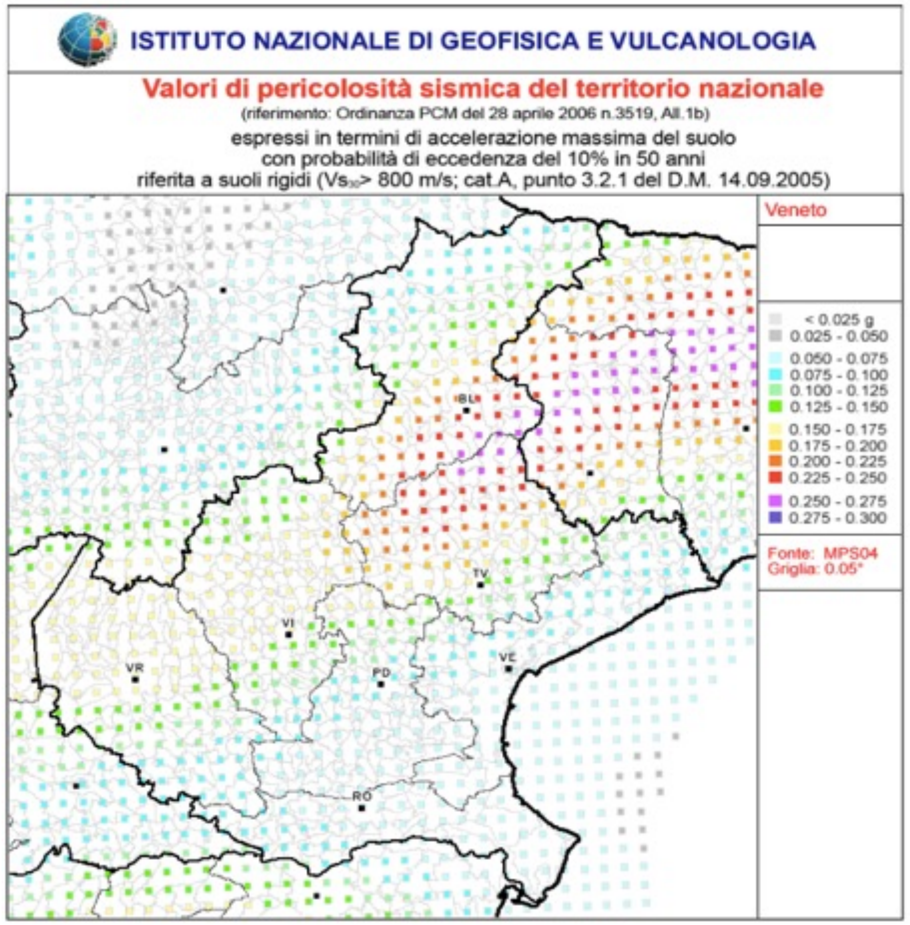


2004



Values of a_g are provided on a grid with steps of 0.05°





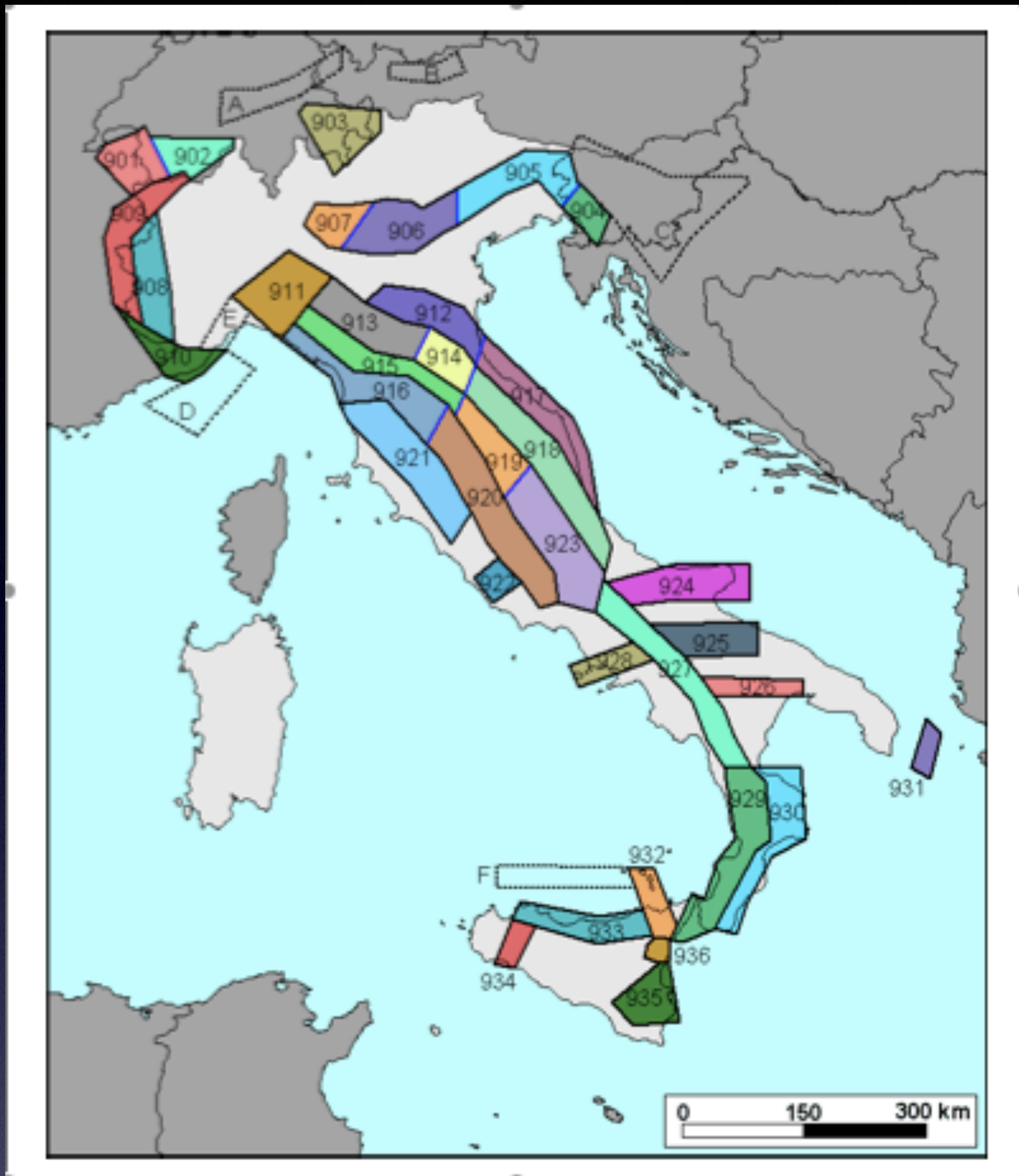
http://esse1.mi.ingv.it/

The actual norm OPCM 3519

Historical Catalog CPTI NT4.1 → Statistic Processing → Map of ground expected acceleration

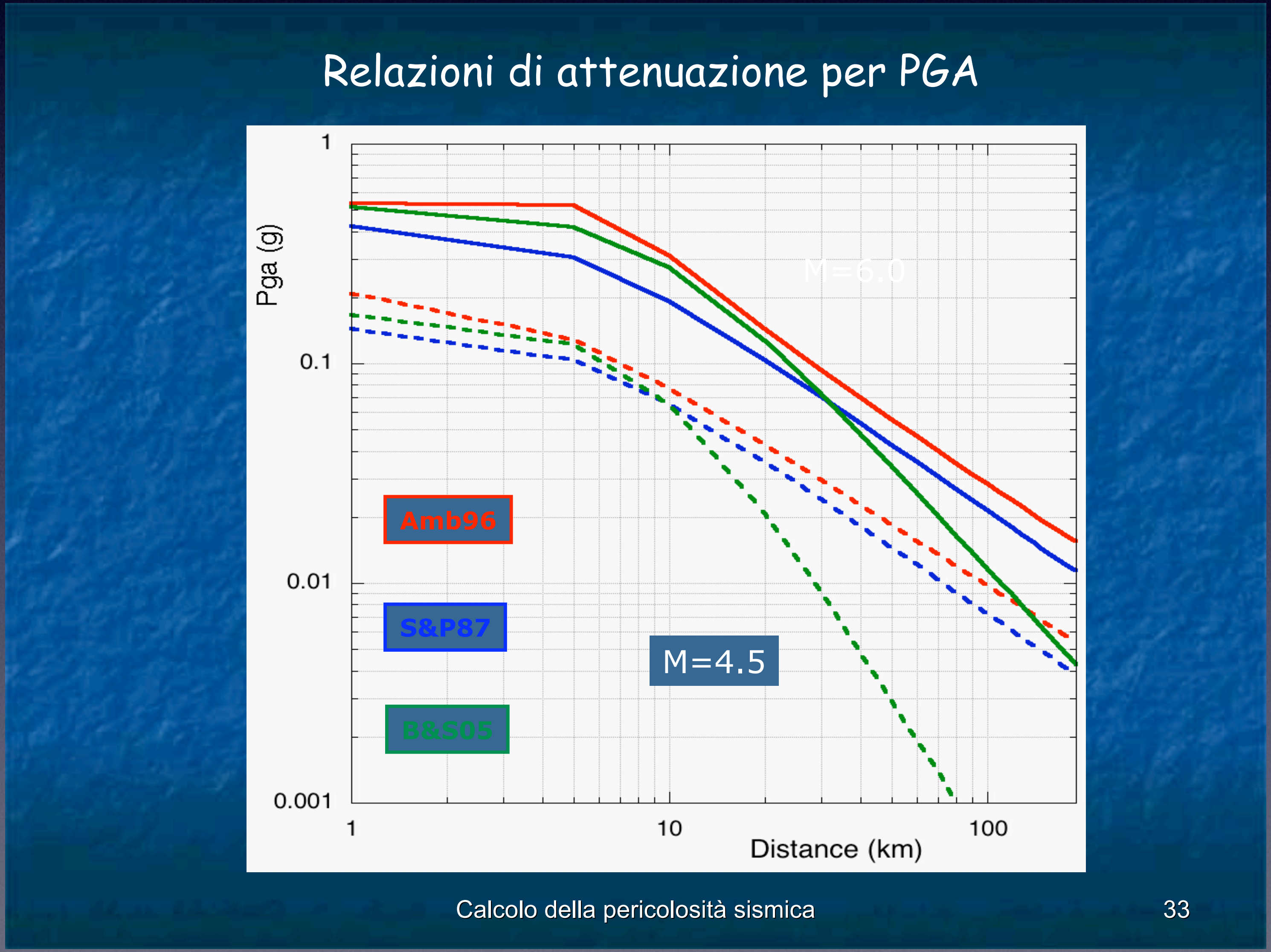
www.ingv.it

Where and how much strong? → Propagation of Energy from the source → Effects



Seismogenic zones

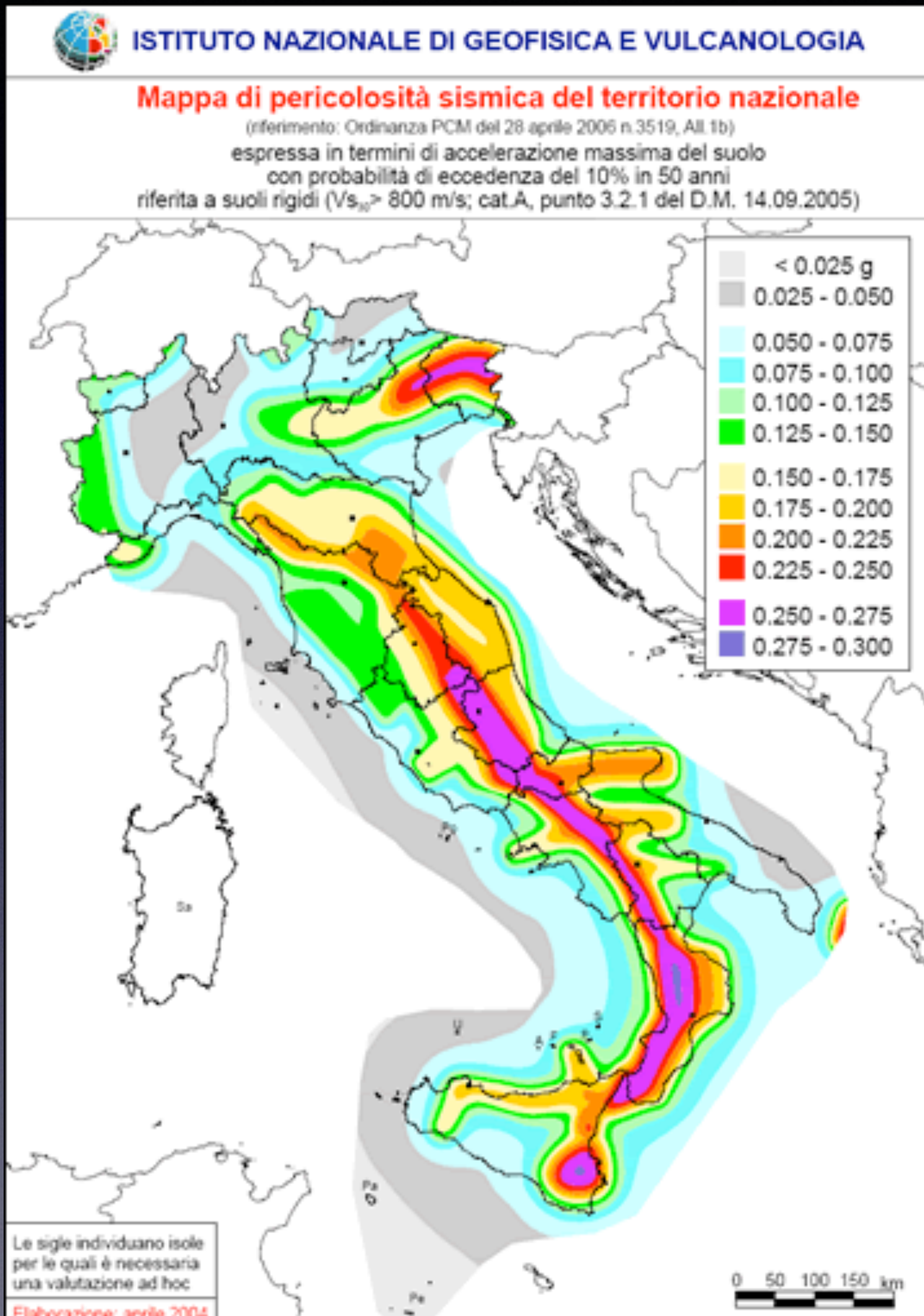
(based on geological structures and past events)



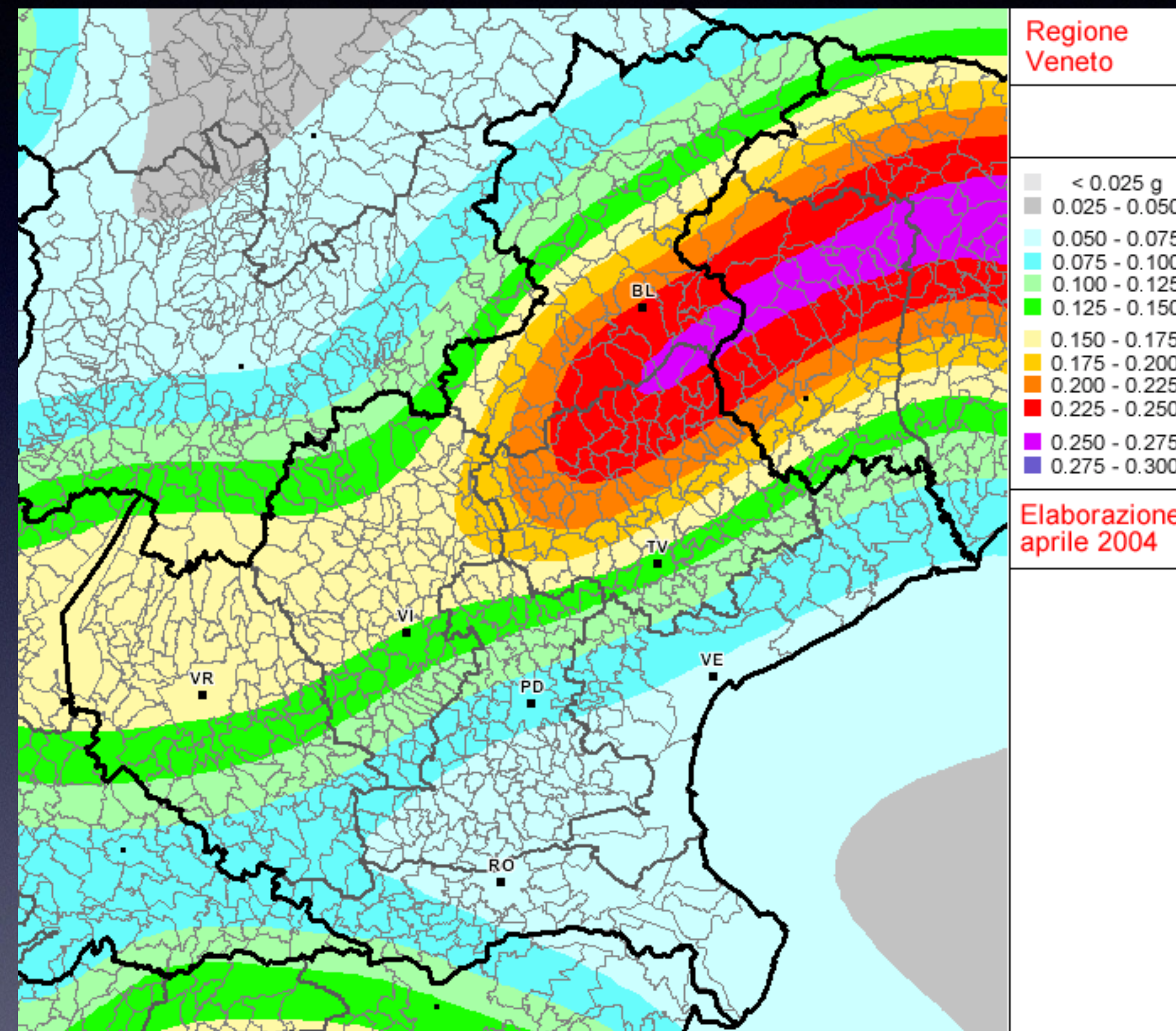
Relation of energy propagation

(based on instrumental estimation with distance)

Final Map



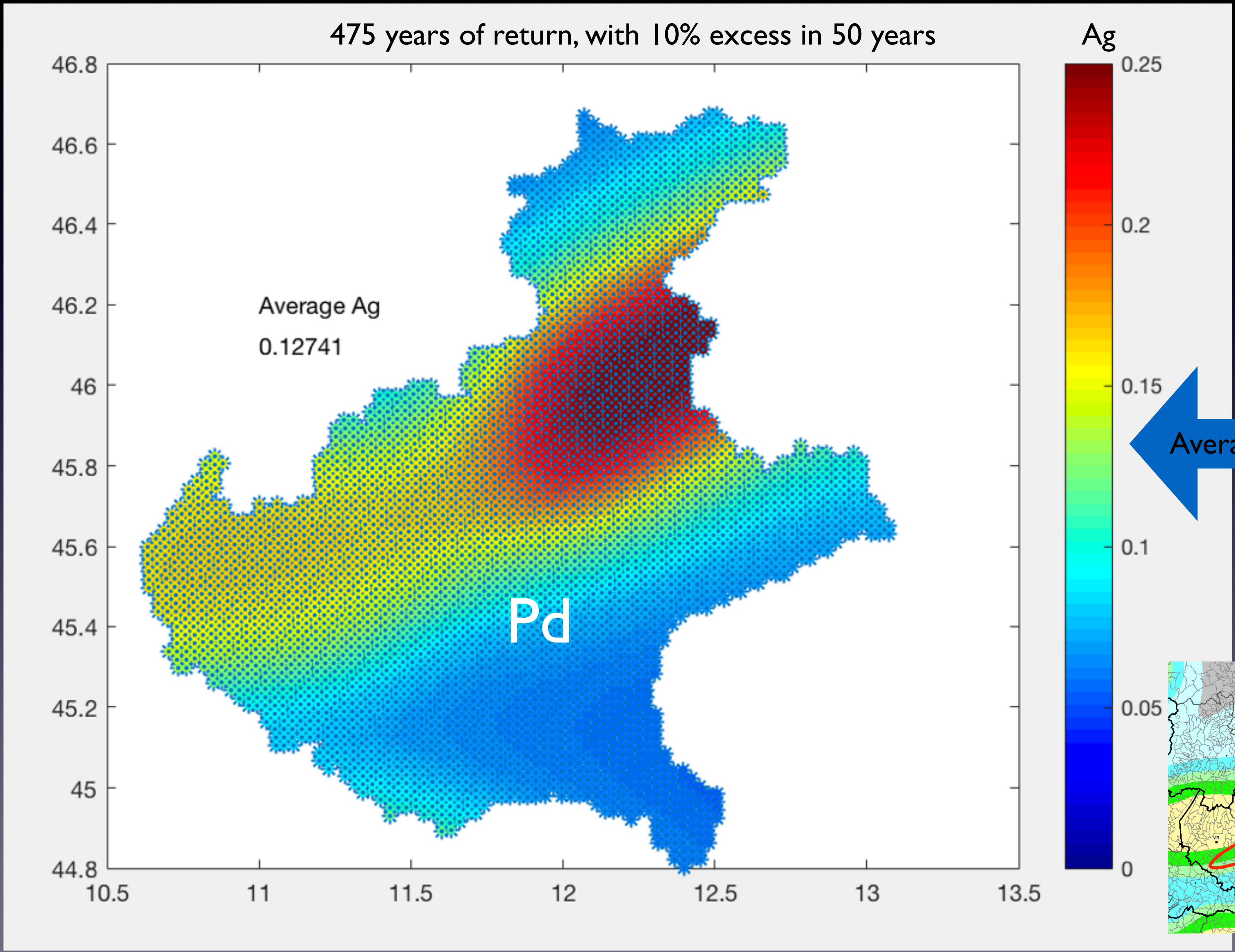
ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA
Mappa di pericolosità sismica del territorio nazionale
(riferimento: Ordinanza PCM del 28 aprile 2006 n.3519, All.1b)
espressa in termini di accelerazione massima del suolo
con probabilità di eccedenza del 10% in 50 anni
riferita a suoli rigidi (Vs30> 800 m/s; cat.A, punto 3.2.1 del D.M. 14.09.2005)
< 0.025 g
0.025 - 0.050
0.050 - 0.075
0.075 - 0.100
0.100 - 0.125
0.125 - 0.150
0.150 - 0.175
0.175 - 0.200
0.200 - 0.225
0.225 - 0.250
0.250 - 0.275
0.275 - 0.300
Le sigle individuano isole per le quali è necessaria una valutazione ad hoc
0 50 100 150 km
Elaborazione: aprile 2004



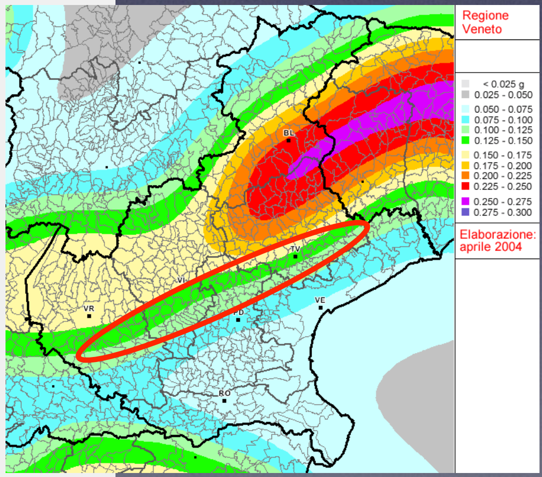
Regione Veneto
< 0.025 g
0.025 - 0.050
0.050 - 0.075
0.075 - 0.100
0.100 - 0.125
0.125 - 0.150
0.150 - 0.175
0.175 - 0.200
0.200 - 0.225
0.225 - 0.250
0.250 - 0.275
0.275 - 0.300
Elaborazione: aprile 2004
BL
TV
VI
VR
PD
VE
RO

Final Map

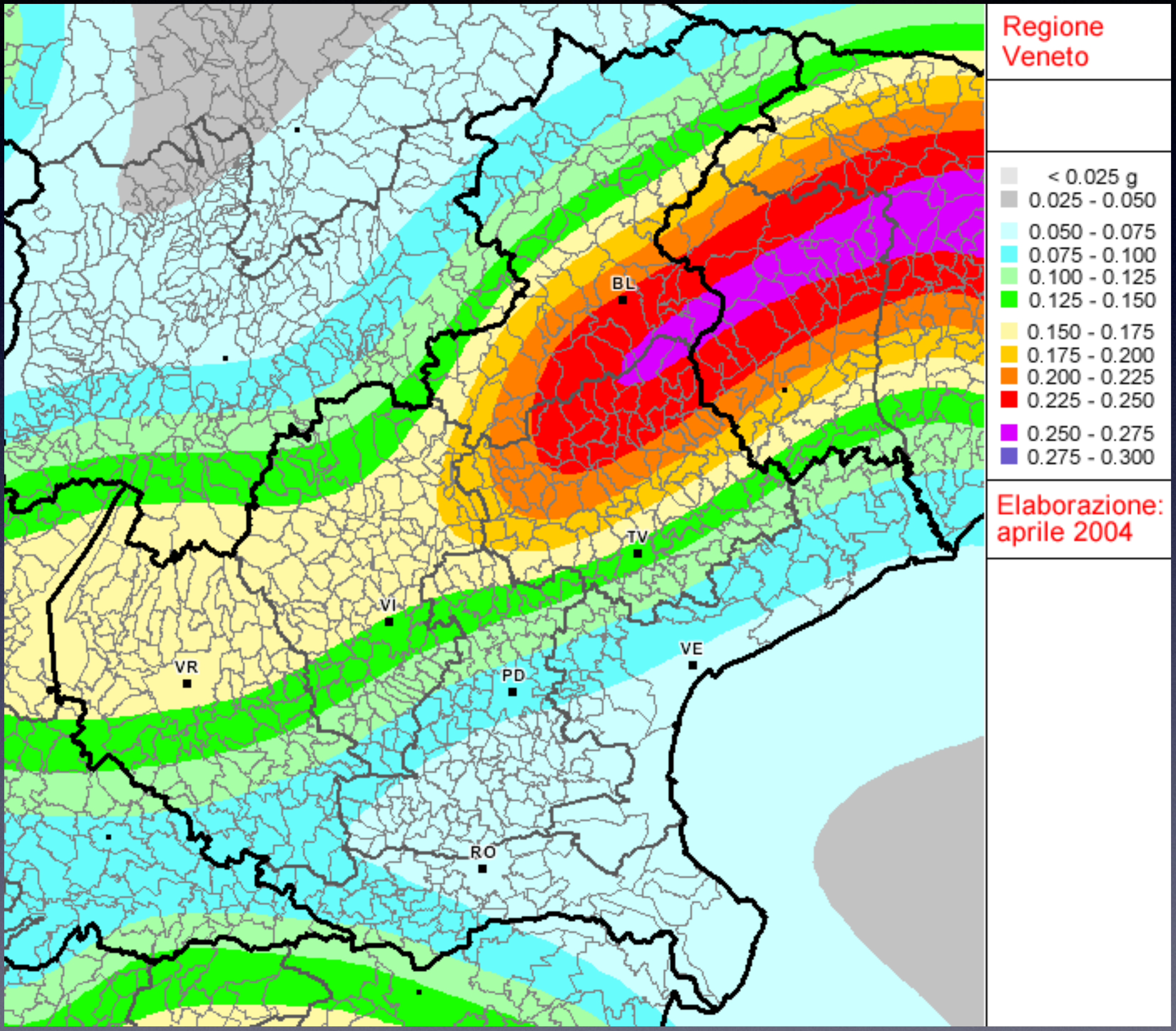
10 km ?



Average

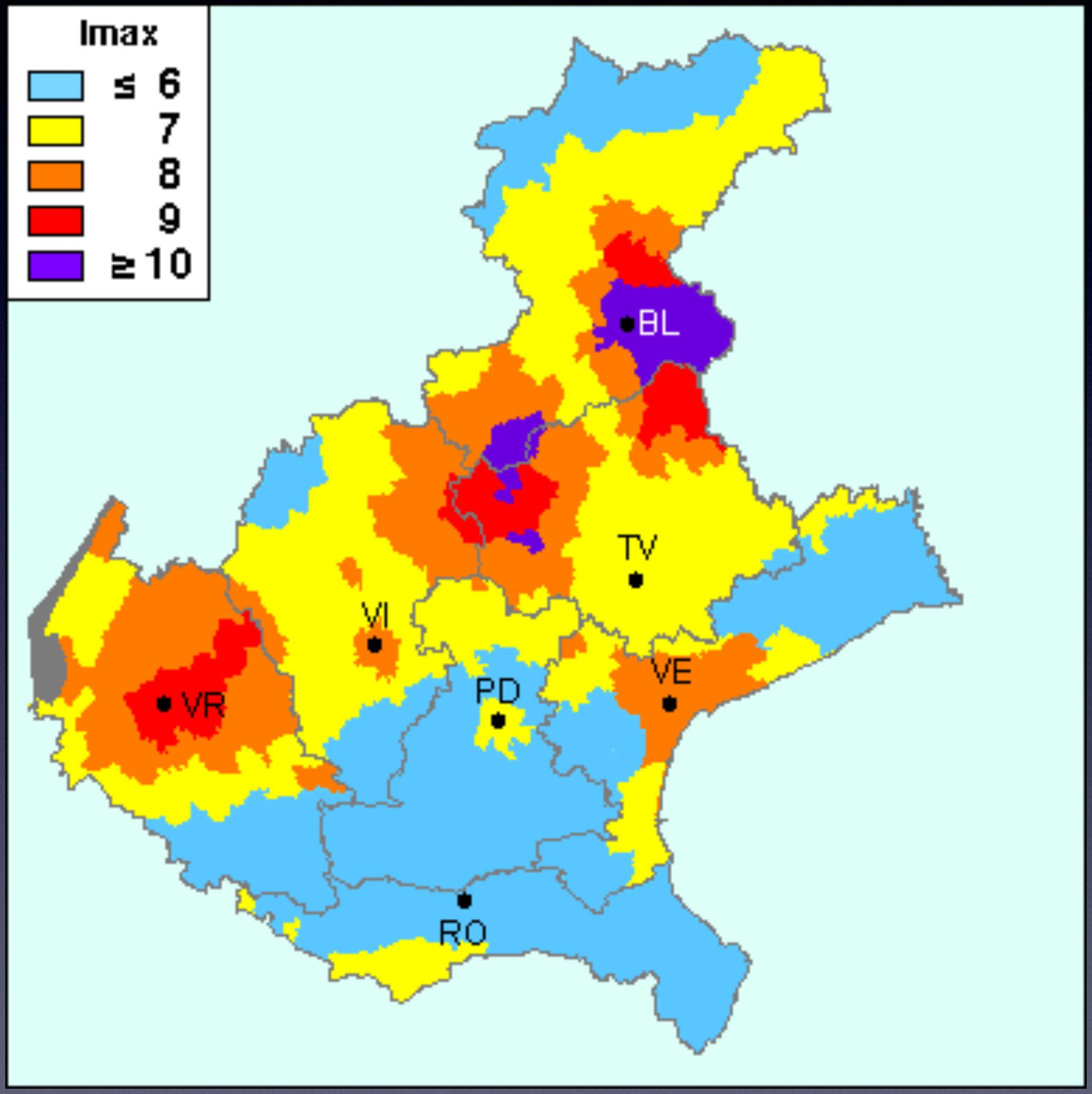


Acceleration Maps

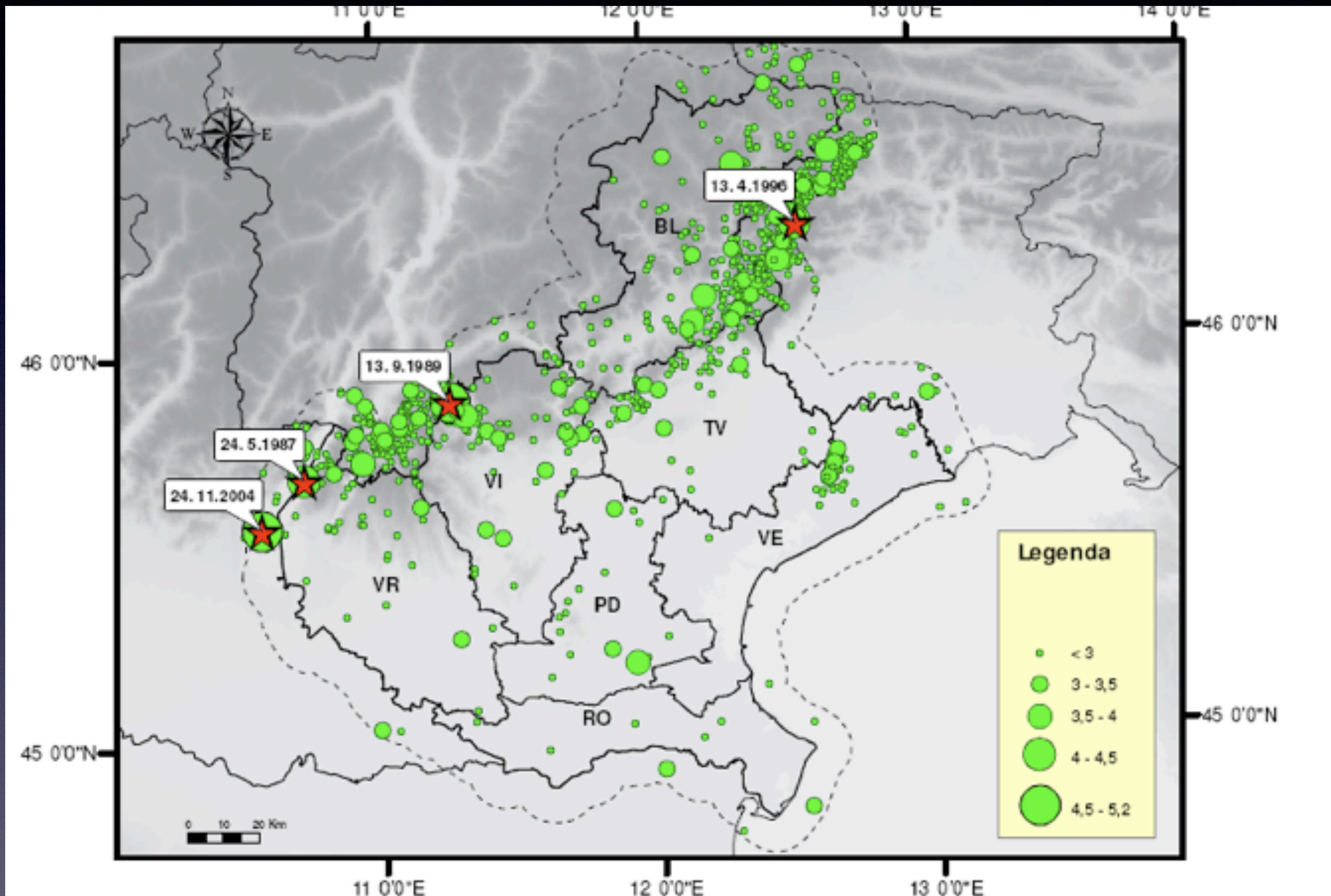


The Veneto Region Example

1117 Verona Imcs 9.0
1491 Verona Imcs 9.0
1511 Venezia Imcs 7.5
1695 Padova Imcs 7.5
1873 Cansiglio Imcs 9.0
1936 Cansiglio Imcs 7.5
1976 Friuli Imcs 6.0
Montello Imcs 9.0 ?



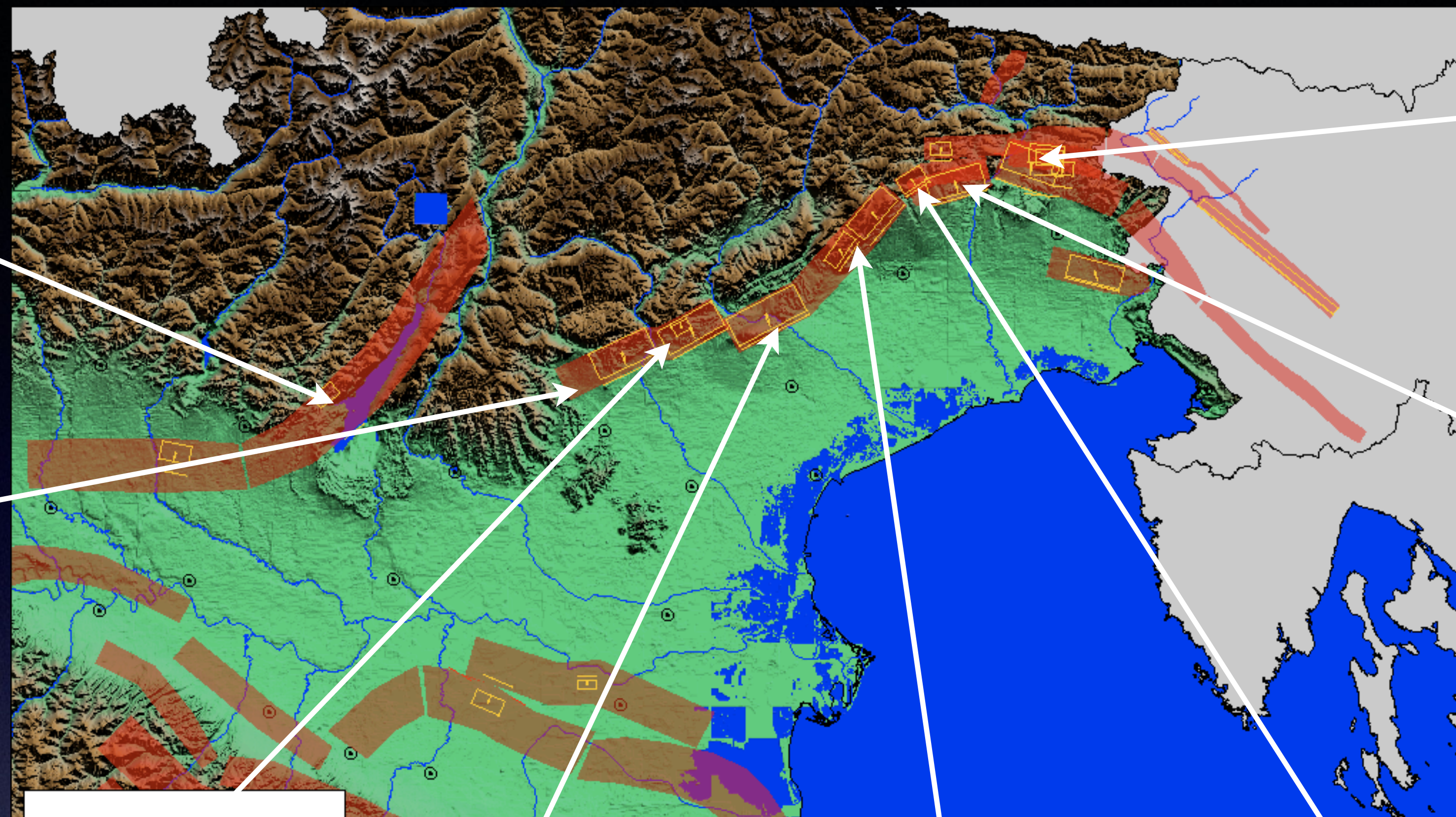
Recorded earthquakes

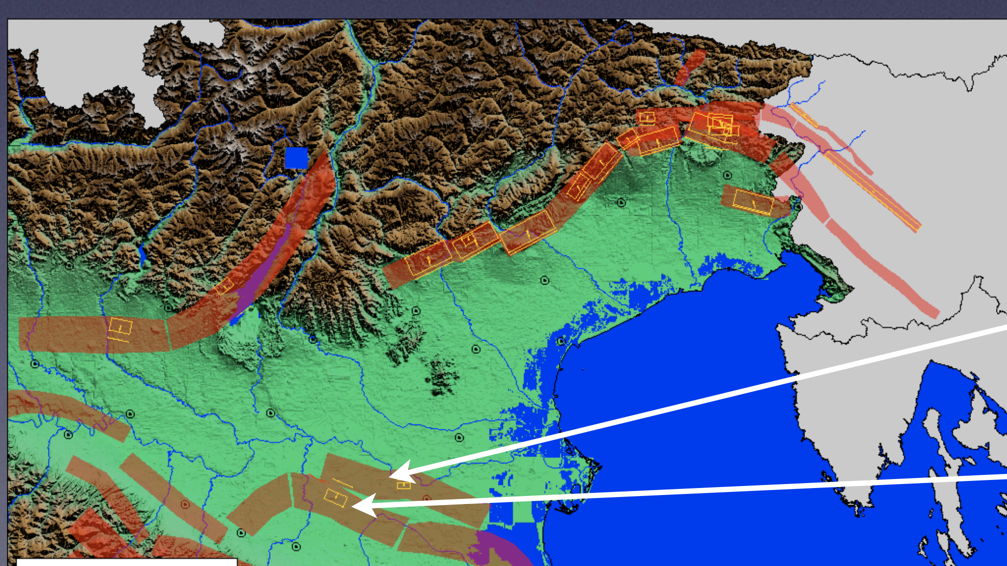


M>4
13.4.1996
13.9.1989
24.5.1987
24.11.2004

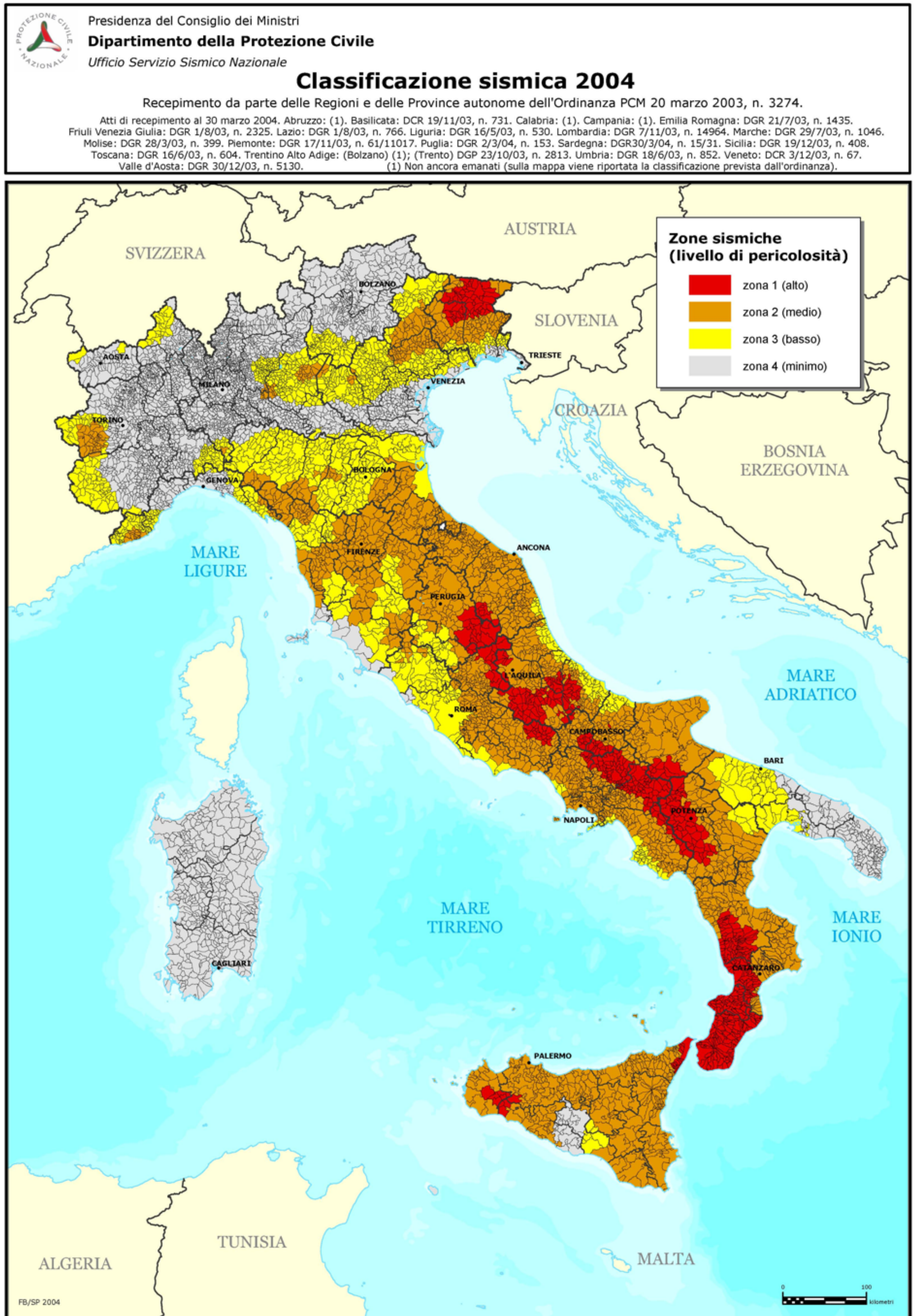
Earthquakes recorded from the OGS seismic network in Veneto 1977 – 2006 (Priolo, 2008). Stars arw M>4

The Veneto seismogenetic zones

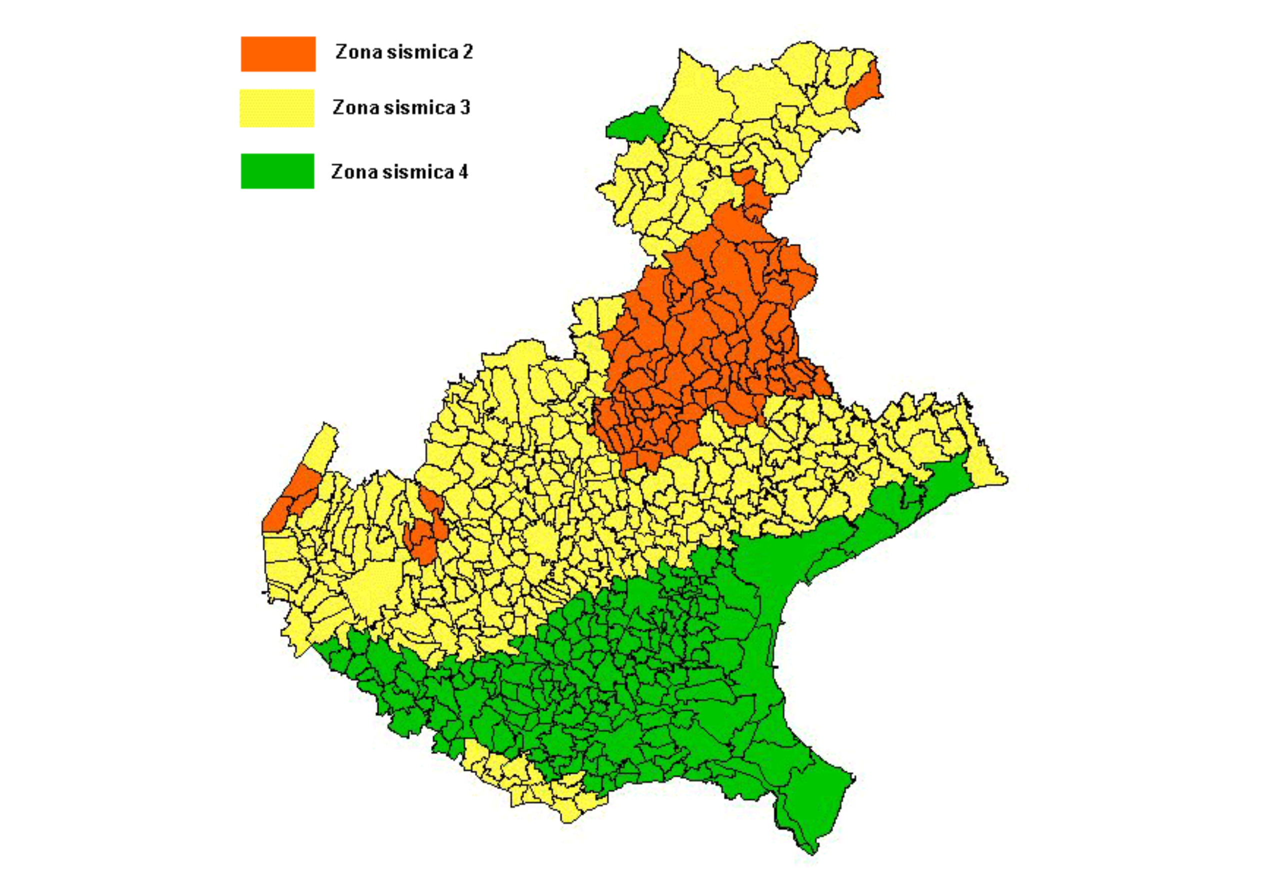




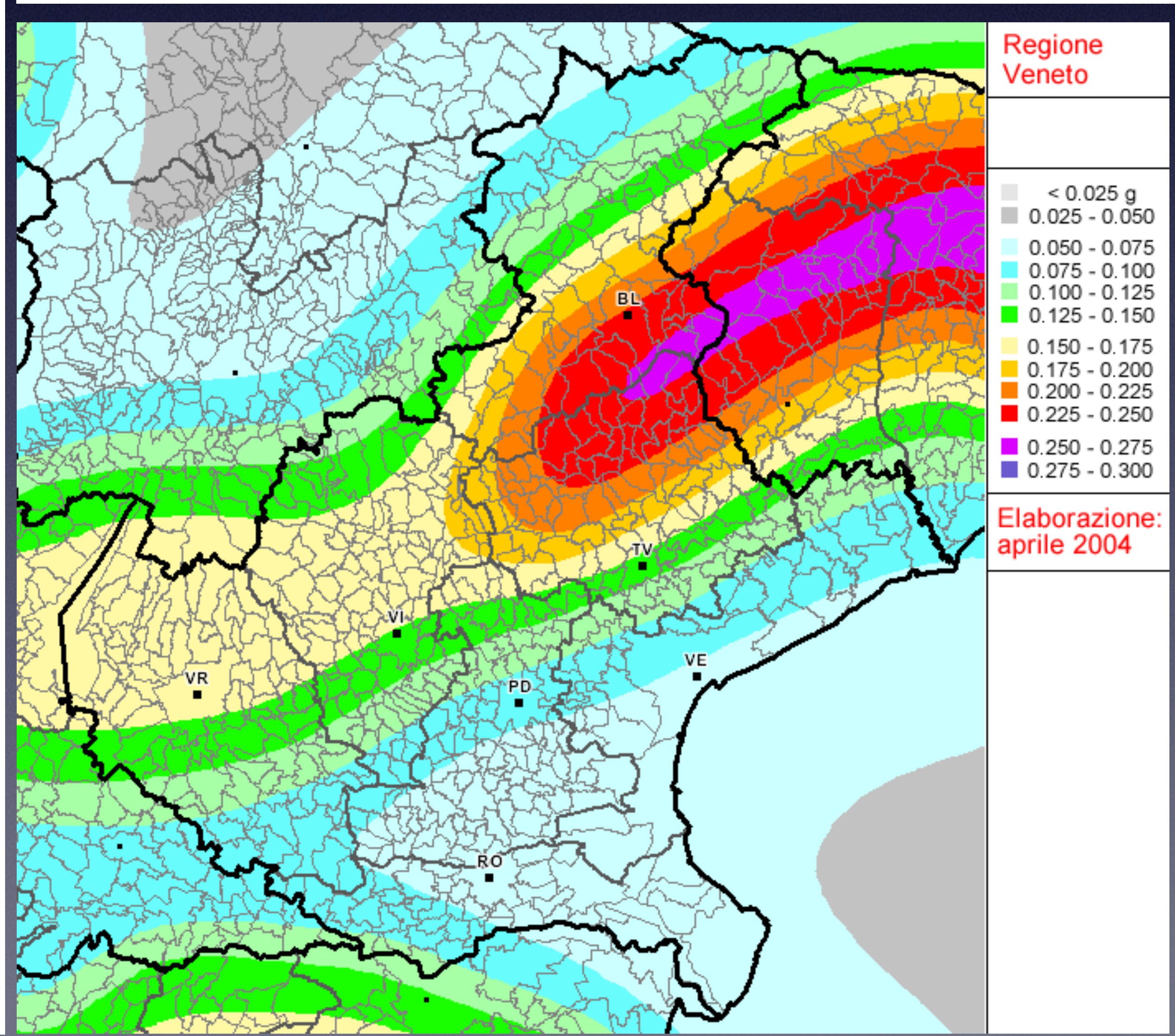
DISS 3 INGV
2003



Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile
Ufficio Servizio Sismico Nazionale
Classificazione sismica 2004
Recepimento da parte delle Regioni e delle Province autonome dell'Ordinanza PCM 20 marzo 2003, n. 3274.
Atti di recepimento al 30 marzo 2004. Abruzzo: (1). Basilicata: DCR 19/11/03, n. 731. Calabria: (1). Campania: (1). Emilia Romagna: DGR 21/7/03, n. 1435. Friuli Venezia Giulia: DGR 1/8/03, n. 2325. Lazio: DGR 1/8/03, n. 766. Liguria: DGR 16/5/03, n. 530. Lombardia: DGR 7/11/03, n. 14964. Marche: DGR 29/7/03, n. 1046. Molise: DGR 28/3/03, n. 399. Piemonte: DGR 17/11/03, n. 61/11017. Puglia: DGR 2/3/04, n. 153. Sardegna: DGR30/3/04, n. 15/31. Sicilia: DGR 19/12/03, n. 408. Toscana: DGR 16/6/03, n. 604. Trentino Alto Adige: (Bolzano) (1); (Trento) DGP 23/10/03, n. 2813. Umbria: DGR 18/6/03, n. 852. Veneto: DCR 3/12/03, n. 67. Valle d'Aosta: DGR 30/12/03, n. 5130.
(1) Non ancora emanati (sulla mappa viene riportata la classificazione prevista dall'ordinanza).
Zone sismiche (livello di pericolosità)
zona 1 (alto)
zona 2 (medio)
zona 3 (basso)
zona 4 (minimo)
SVIZZERA
AUSTRIA
SLOVENIA
CROAZIA
BOSNIA ERZEGOVINA
MARE LIGURE
MARE ADRIATICO
MARE TIRRENO
MARE IONIO
TUNISIA
ALGERIA
MALTA
FB/SP 2004



Zona sismica 2
Zona sismica 3
Zona sismica 4



Regione Veneto
< 0.025 g
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0.175 - 0.200
0.200 - 0.225
0.225 - 0.250
0.250 - 0.275
0.275 - 0.300
Elaborazione: aprile 2004
BL
TV
VI
VR
PD
VE
RO

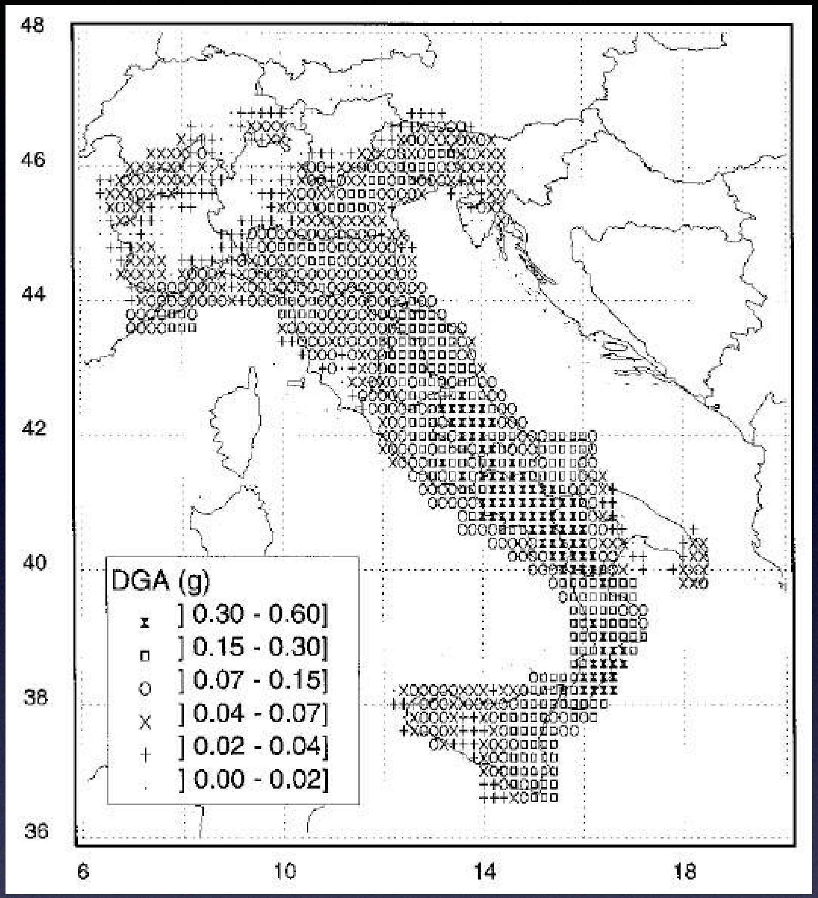
To overcome uncertainties
we cannot use only sensors, we need the quake

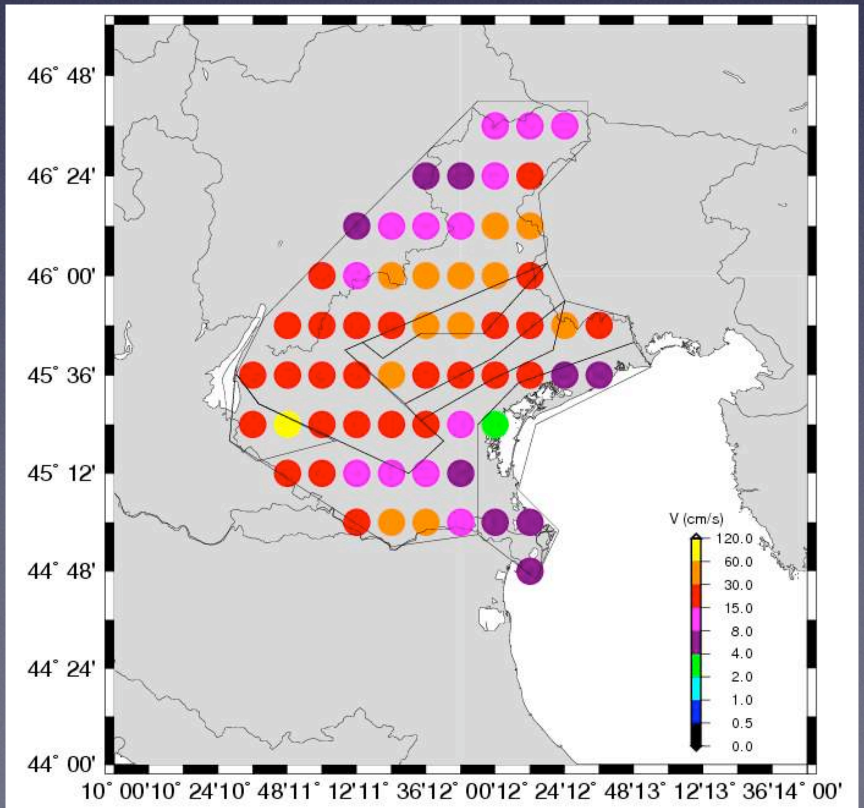
Deterministic Approach

-I select an event (also historical one)

-I select a soil model correctly parameterised

-I compute a synthetic seismogram





The seismic monitoring

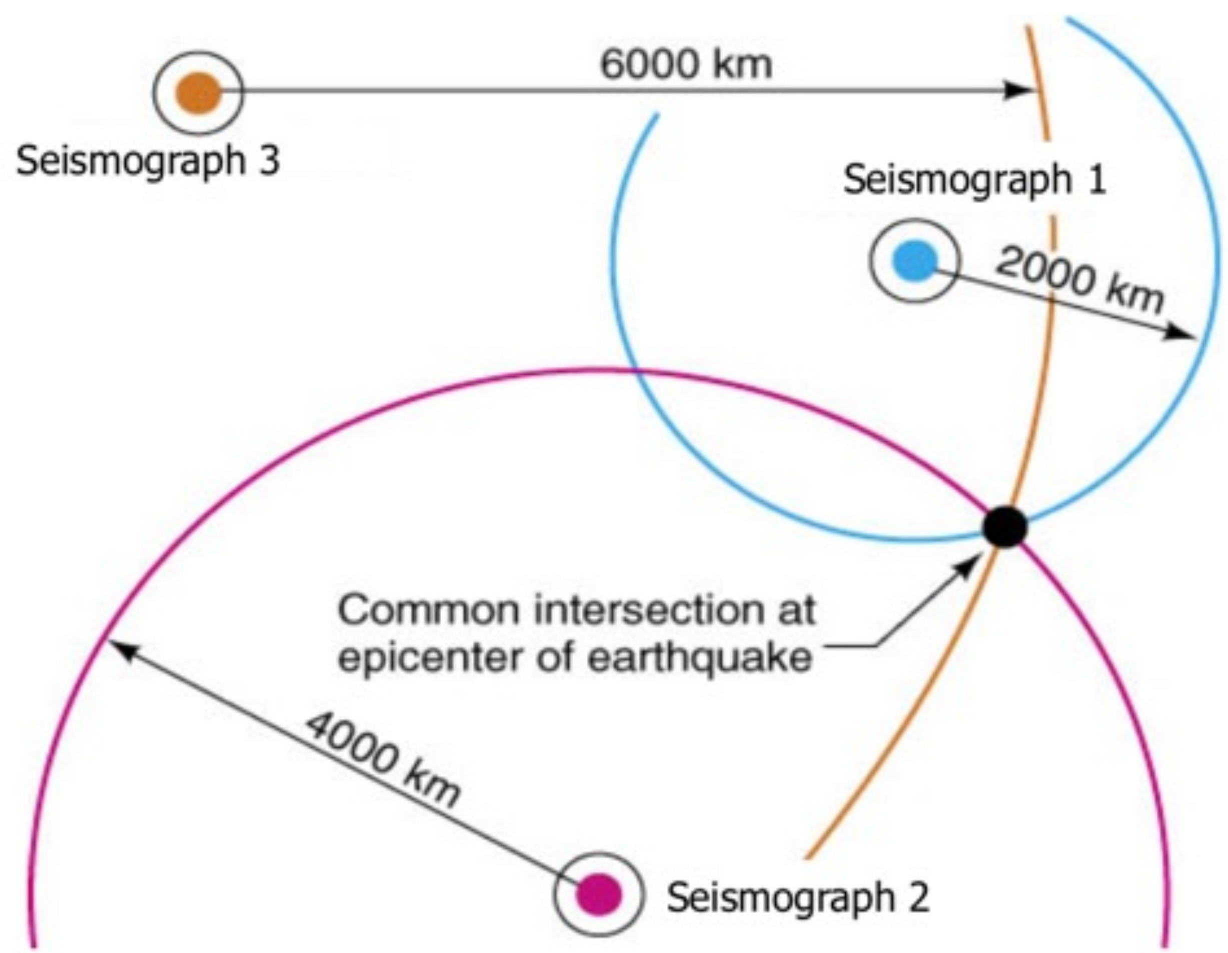
Local and National network

www.ingv.it Istituto Nazionale di Geofisica e Vulcanologia

accessed 07/04/2015

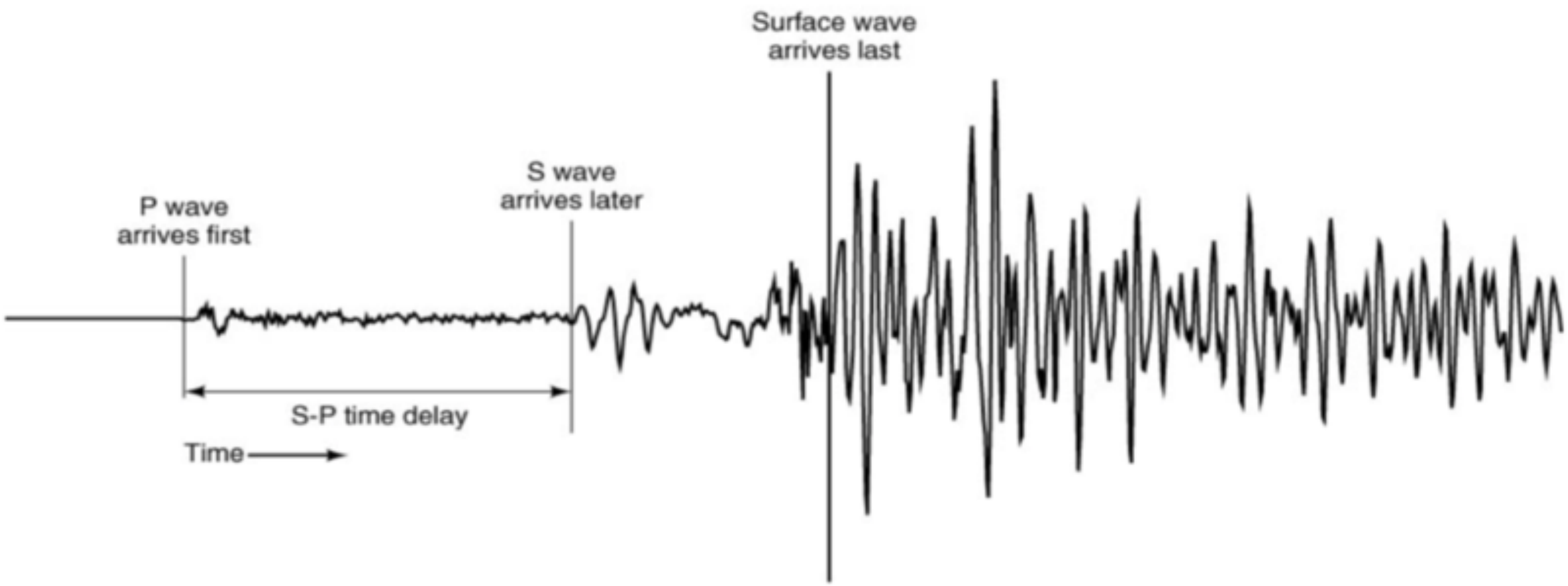
LOCATION OF EARTHQUAKES

The location of an earthquake is specified in terms of the location of its **epicenter**. Epicentral location is based on the relative arrival times of P and S waves at a set of at least 3 seismographs.

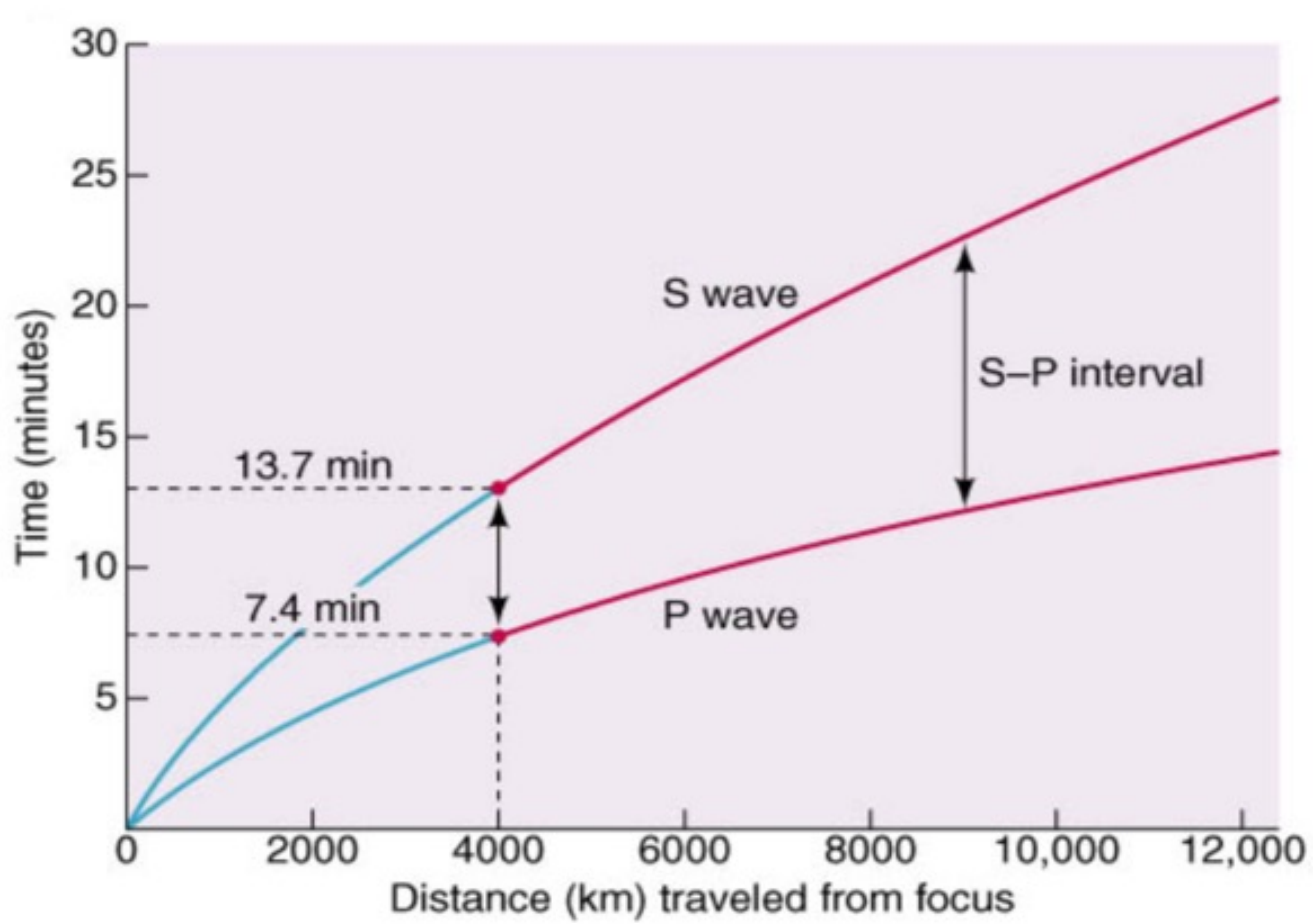


LOCATION OF EARTHQUAKES

P waves travel faster than S waves → P waves will arrive first at the seismograph
The difference in arrival times depends on the distance between the focus and the seismograph and on the difference between P and S waves velocities.



The further a seismograph is from a given epicenter, the greater the time gap between the arrival of P and S waves



GROUND MOTION PARAMETERS

Ground motion parameters are fundamental to describe the important characteristics of strong ground motion in a quantitative form.

The most significant characteristics of earthquake motion are:

- **Amplitude**
- **Frequency content**
- **Duration of the motion**

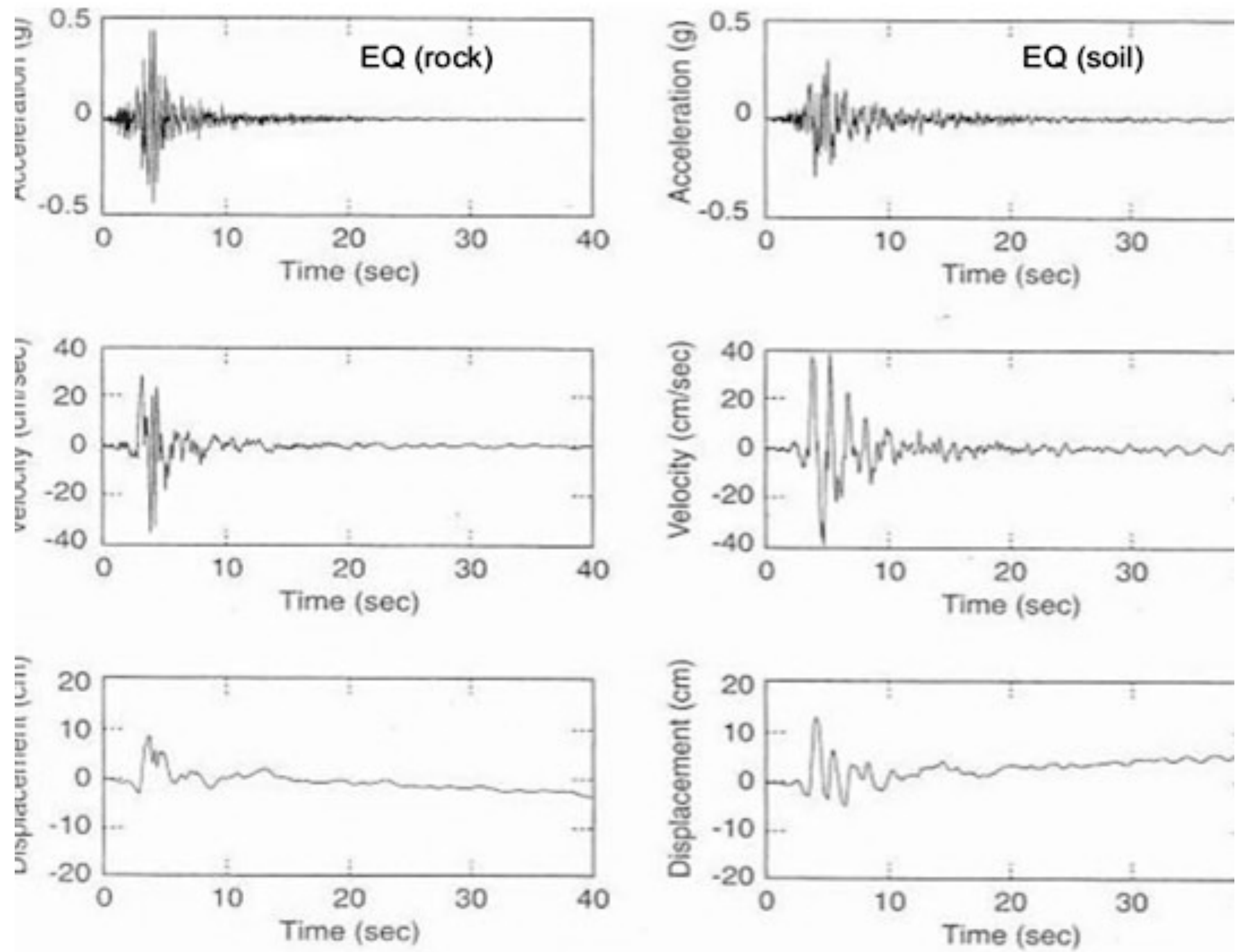
There are other ground motion parameters, that reflect simultaneously 2 or 3 important ground motion characteristics (amplitude, frequency content or duration). Common parameters, that reflects the 3 main ground motion characteristics, are the Arias intensity, the cumulative absolute velocity, and the spectral intensity.

AMPLITUDE PARAMETERS

Ground motion is usually described with a time history of **acceleration, velocity, displacement** or all three.

Typically, one of these quantities is directly measured and the others are obtained from it by integration or differentiation.

The acceleration time history shows a significant proportion of relatively high frequencies, while the displacement time history is dominated by relatively low frequency motion (integration produces a smoothing effect).



AMPLITUDE PARAMETERS

The most common measure of a ground motion amplitude is the peak horizontal acceleration, also known as **peak ground acceleration (PGA)**.

The peak horizontal acceleration for a given component of motion is the largest absolute value of horizontal acceleration obtained from the accelerogram of that component. It can be correlated to earthquake intensity (useful for estimation of peak horizontal acceleration for pre-instrumental earthquakes).

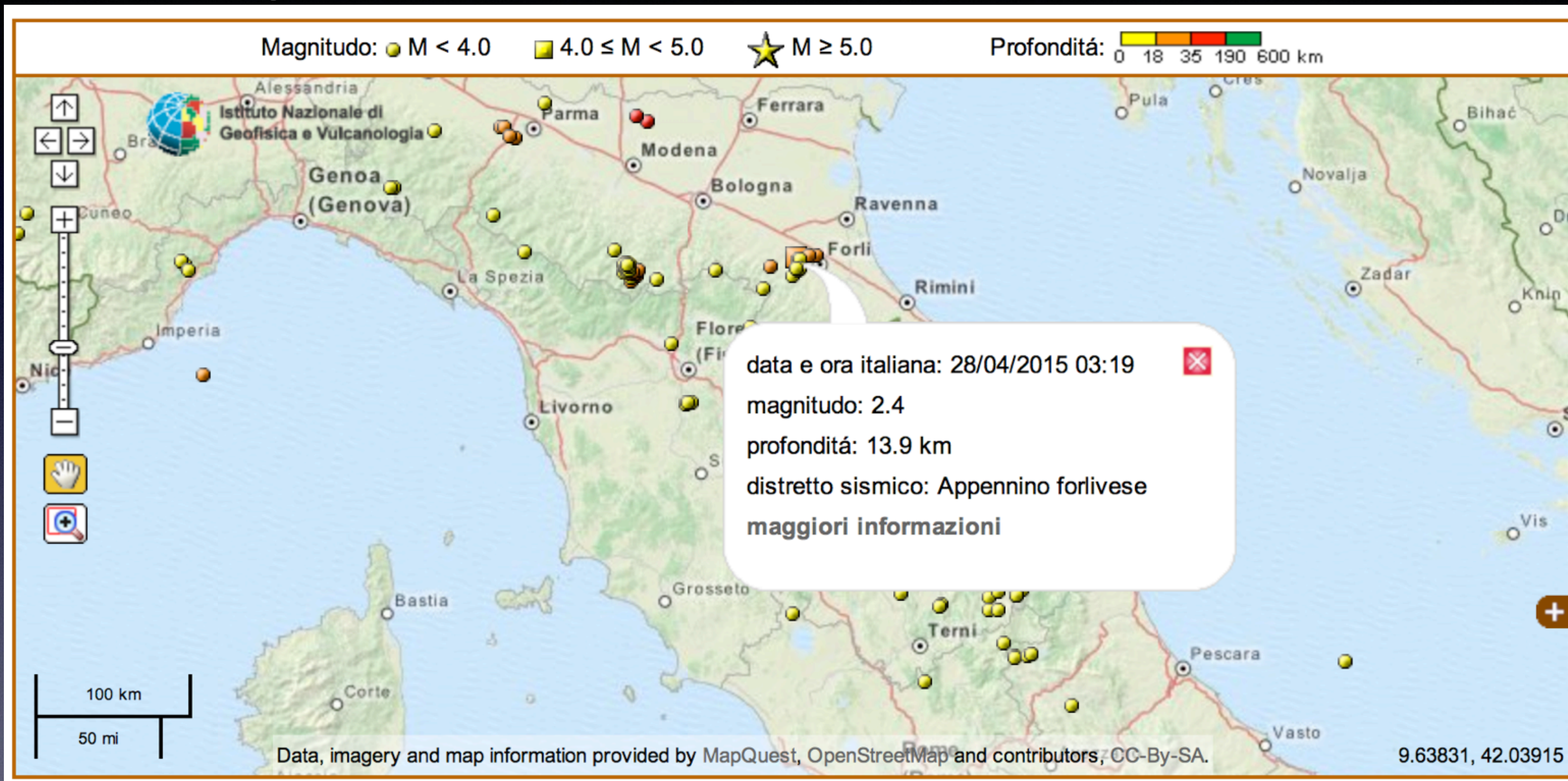
Peak horizontal acceleration is a very useful parameter, but it must be related to additional information in order to characterize a ground motion accurately.

The peak horizontal velocity is another useful parameter for the characterization of ground motion amplitude.

OGS

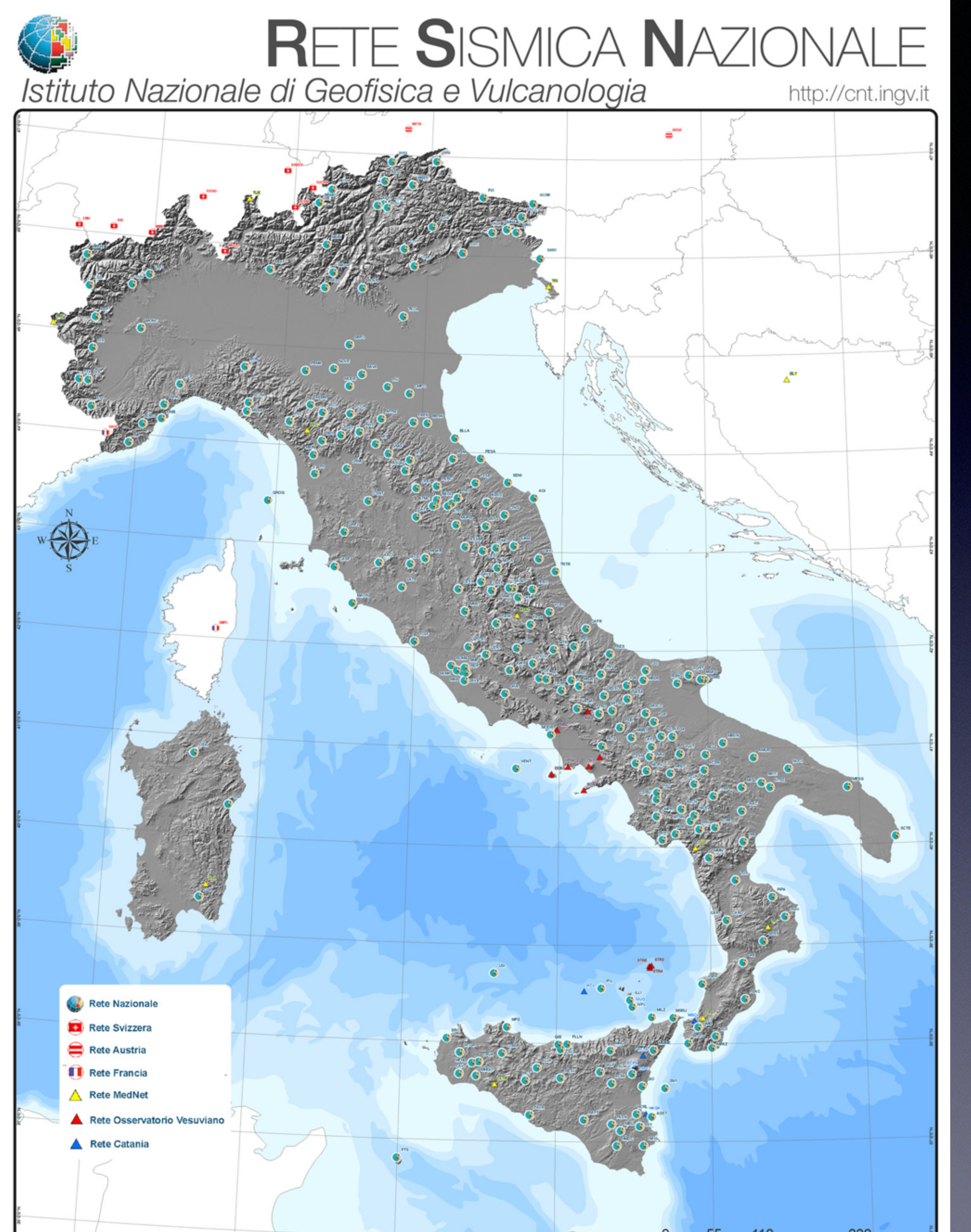
The seismic monitoring

www.ingv.it Istituto Nazionale di Geofisica e Vulcanologia

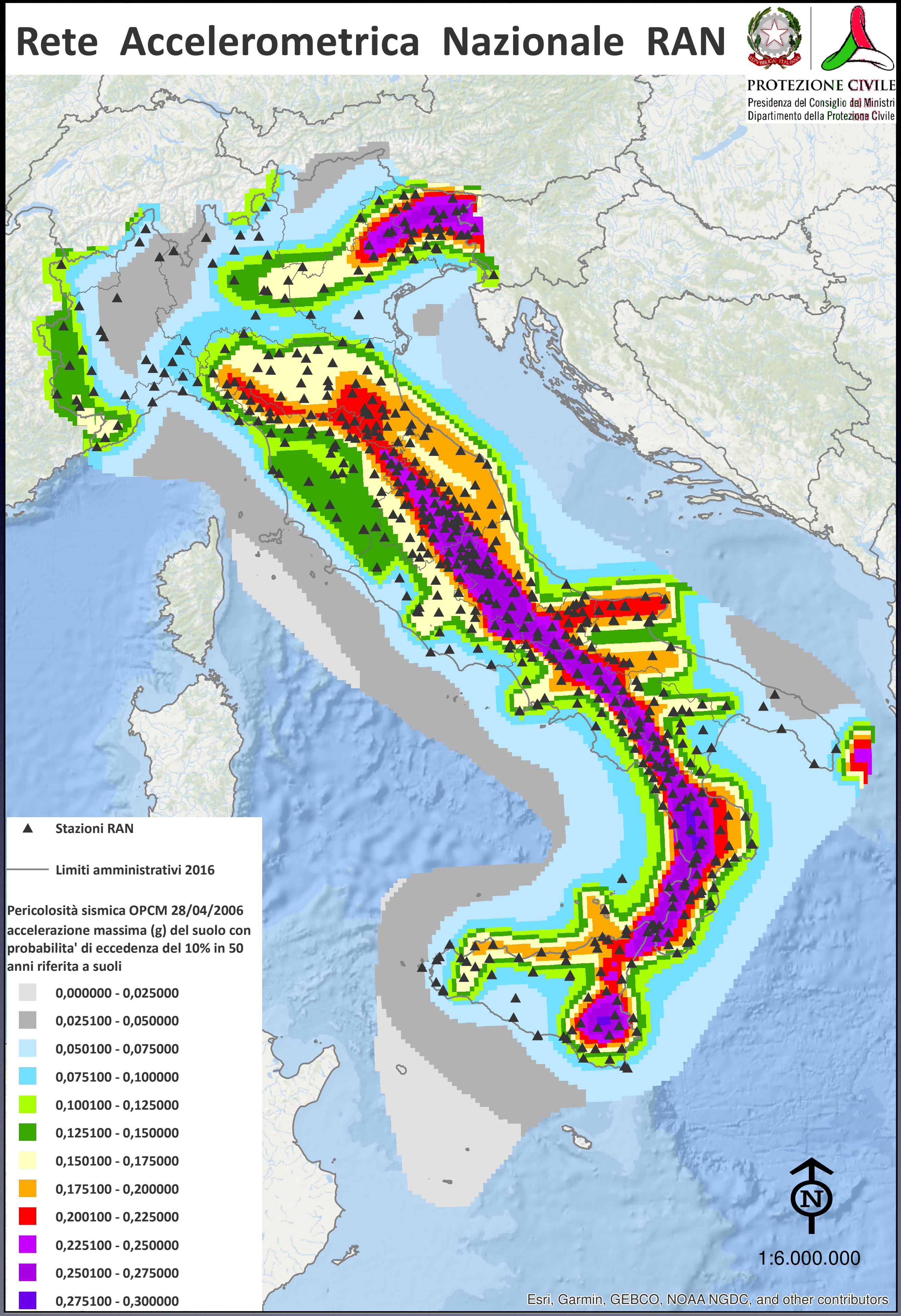


The seismic National Network

High quality Force balanced Seismometers



The seismic National Network

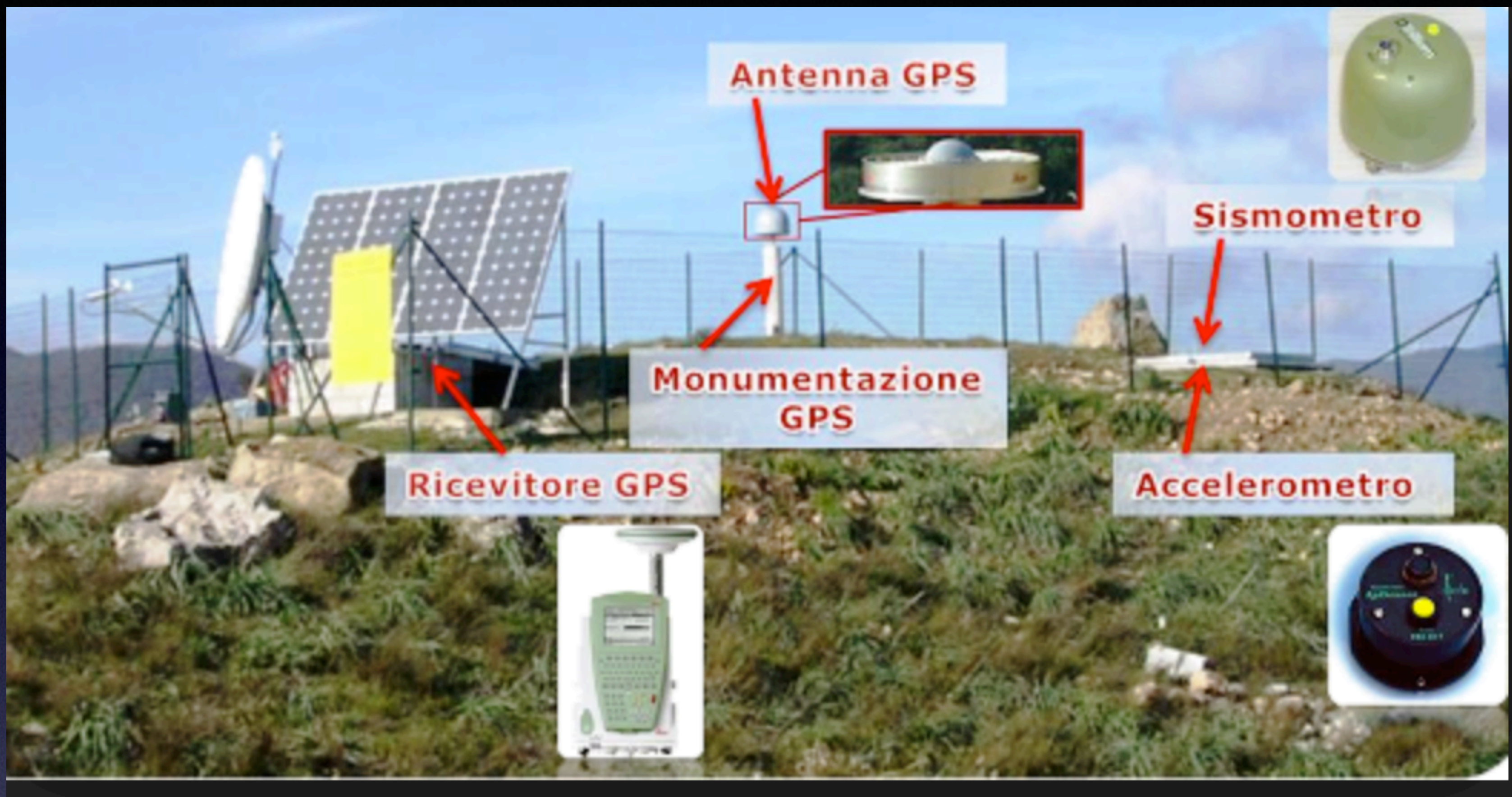


Accelerometers

ran.protezionecivile.it

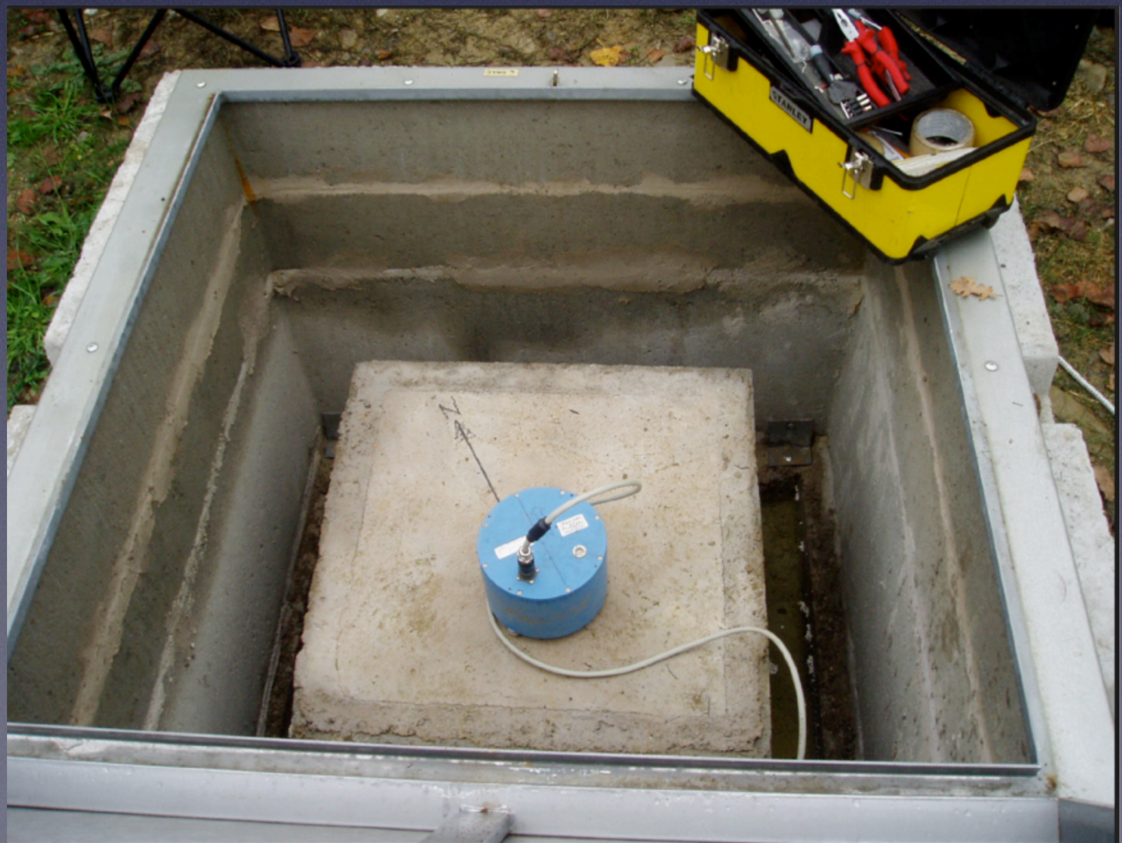
The seismic network

Fixed station in continuous monitoring

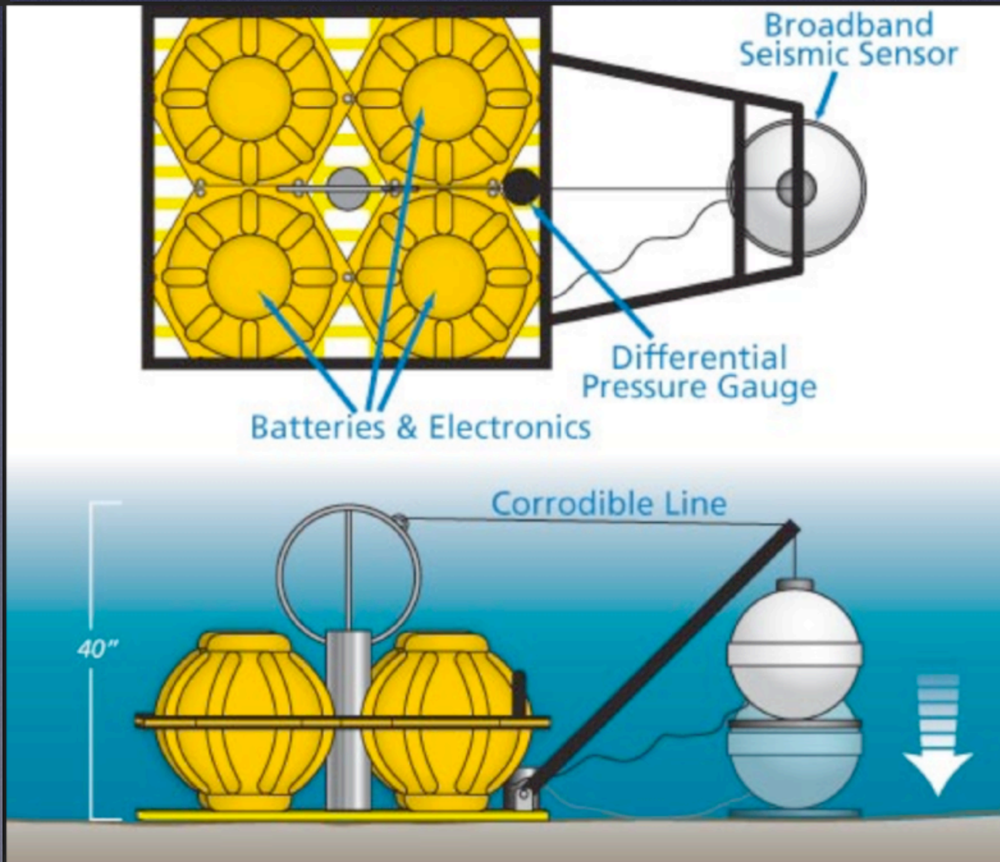


Borehole

Sea bottom



Installed
on
rigid basement



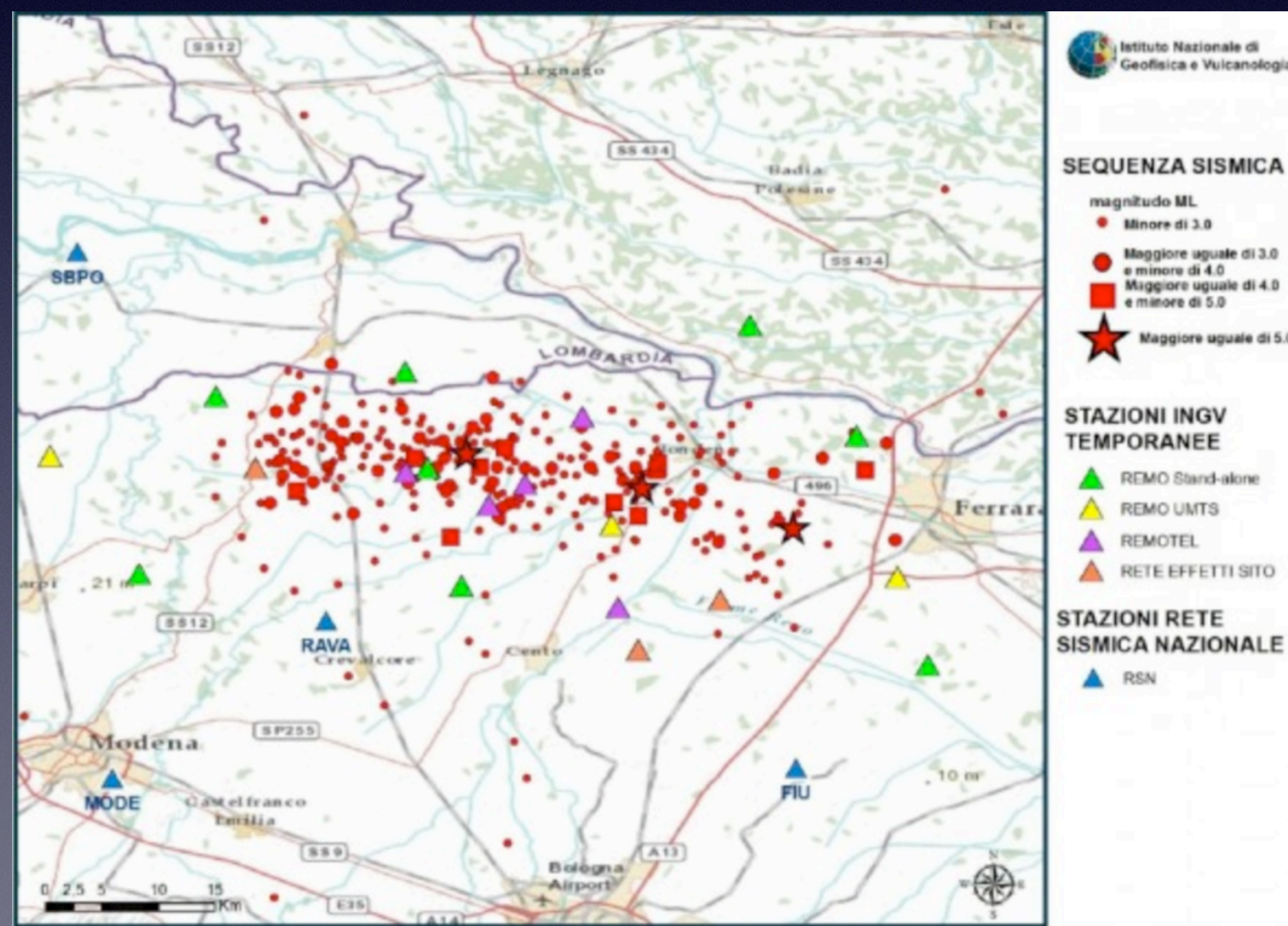
The seismic monitoring

Mobile stations

Installed after a big events to record thousands of after-shocks
Very important for structural studies and characterization

Mobile network Emilia earthquake

mobile station



www.ingv.it

The seismic monitoring
The local seismic network

Several institutions manage local network of relevant importance

N-E Italy OGS network
(Ist. Naz. di Oceanografia e Geofisica sperimentale - Trieste)
www.crs.inogs.it

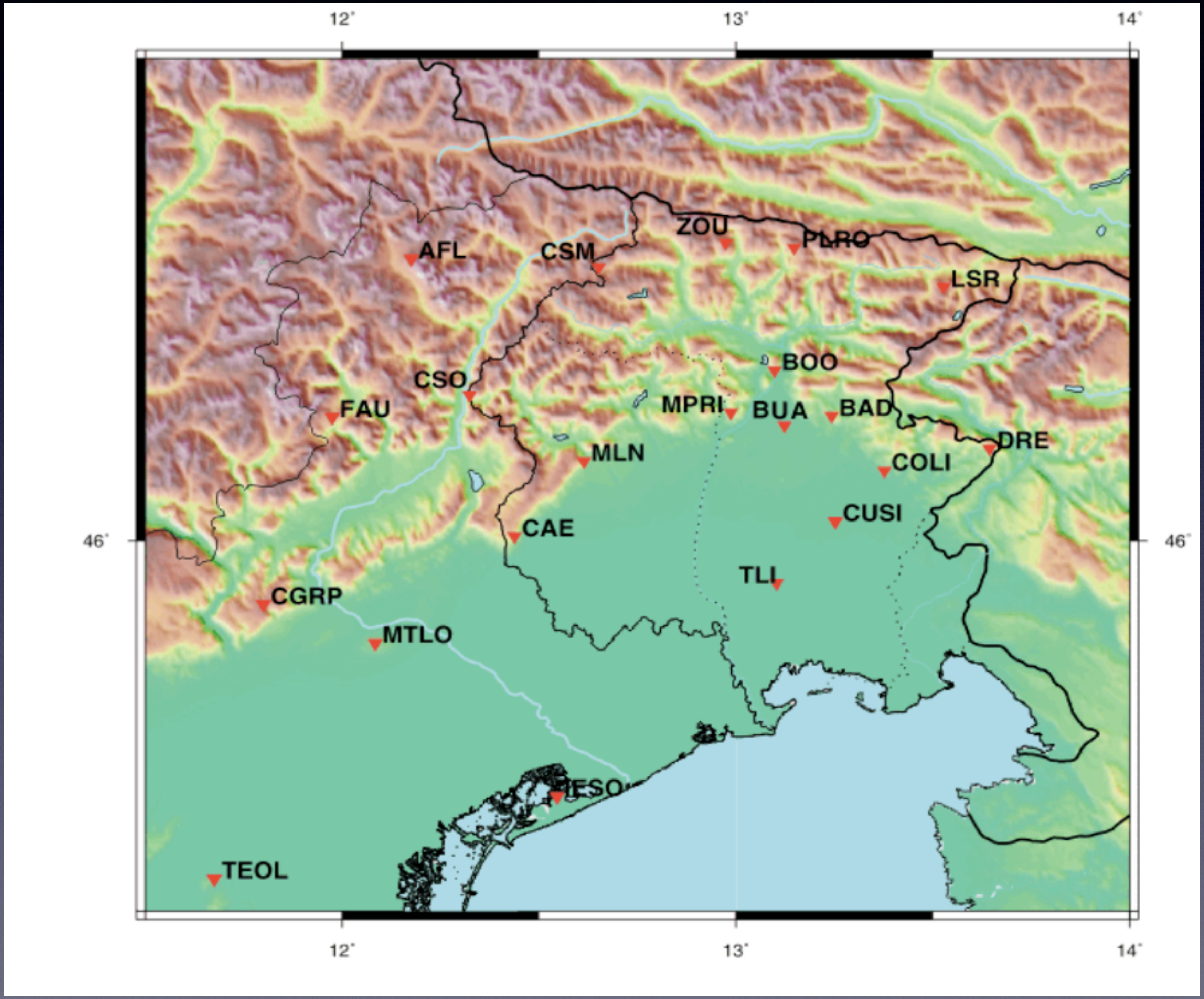
e.g. Trentino Region
rete sismometrica
della Provincia di Trento
http://www.protezionecivile.tn.it/

The seismic monitoring
Seismic local network

www.crs.inogs.it

Rete Centro Ricerche Sismologiche - CRS OGS

(Udine)

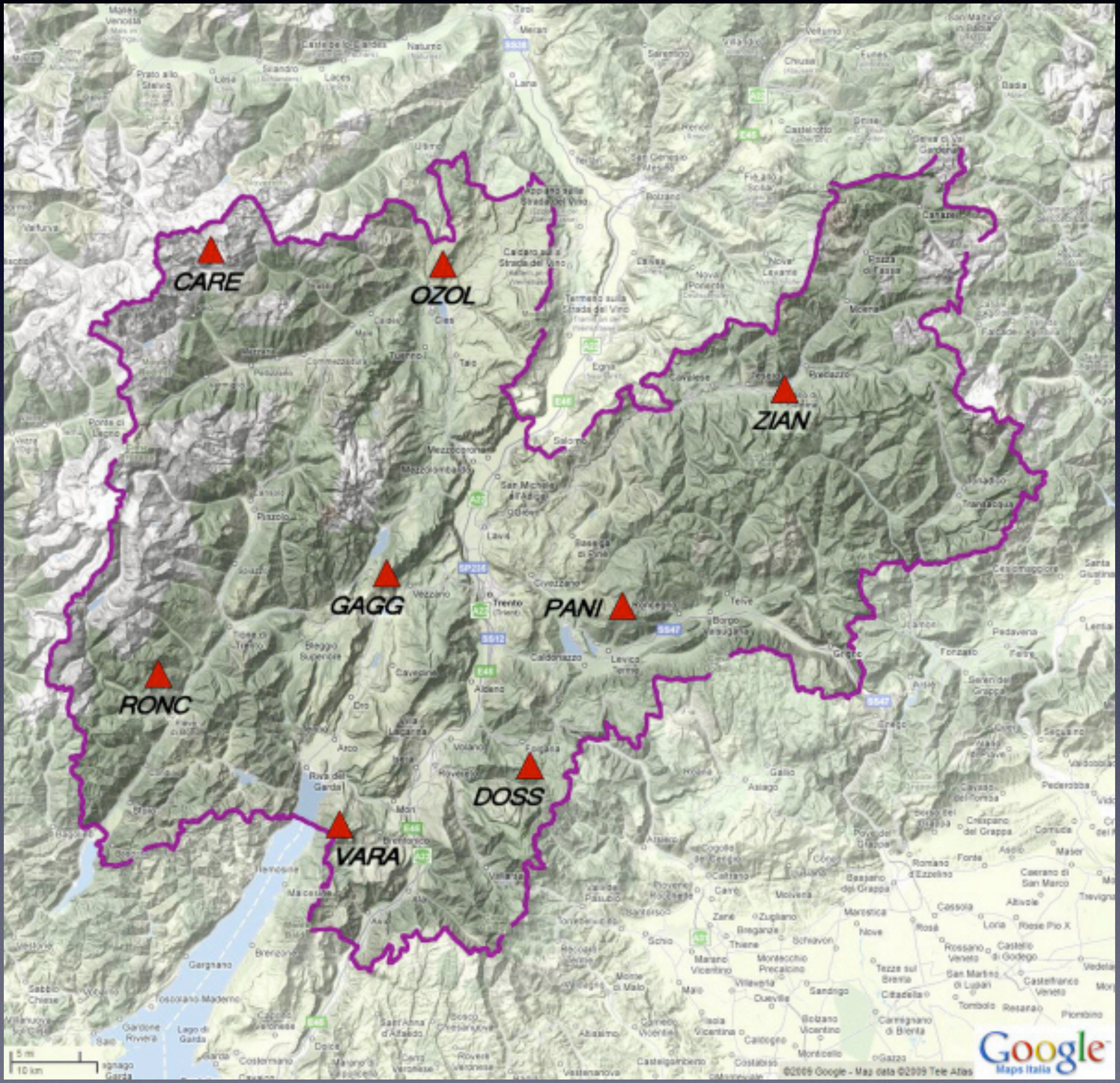


The seismic monitoring
Seismic local network

http://www.protezionecivile.tn.it/

Rete Provincia Autonoma di Trento

(Trento)



The seismic monitoring
Seismic local network

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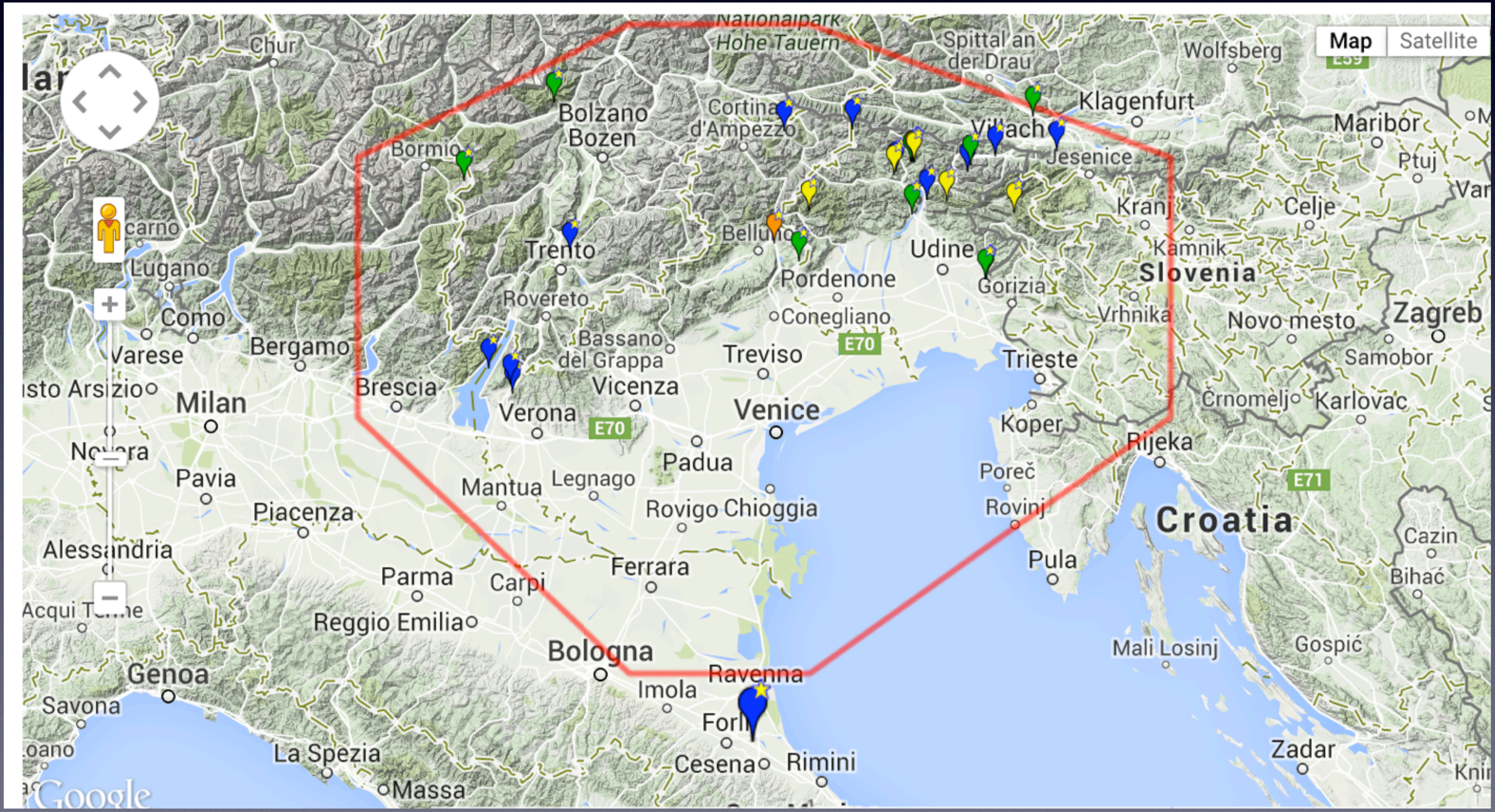
Earthquakes april-may 2015



The seismic monitoring
Seismic local network

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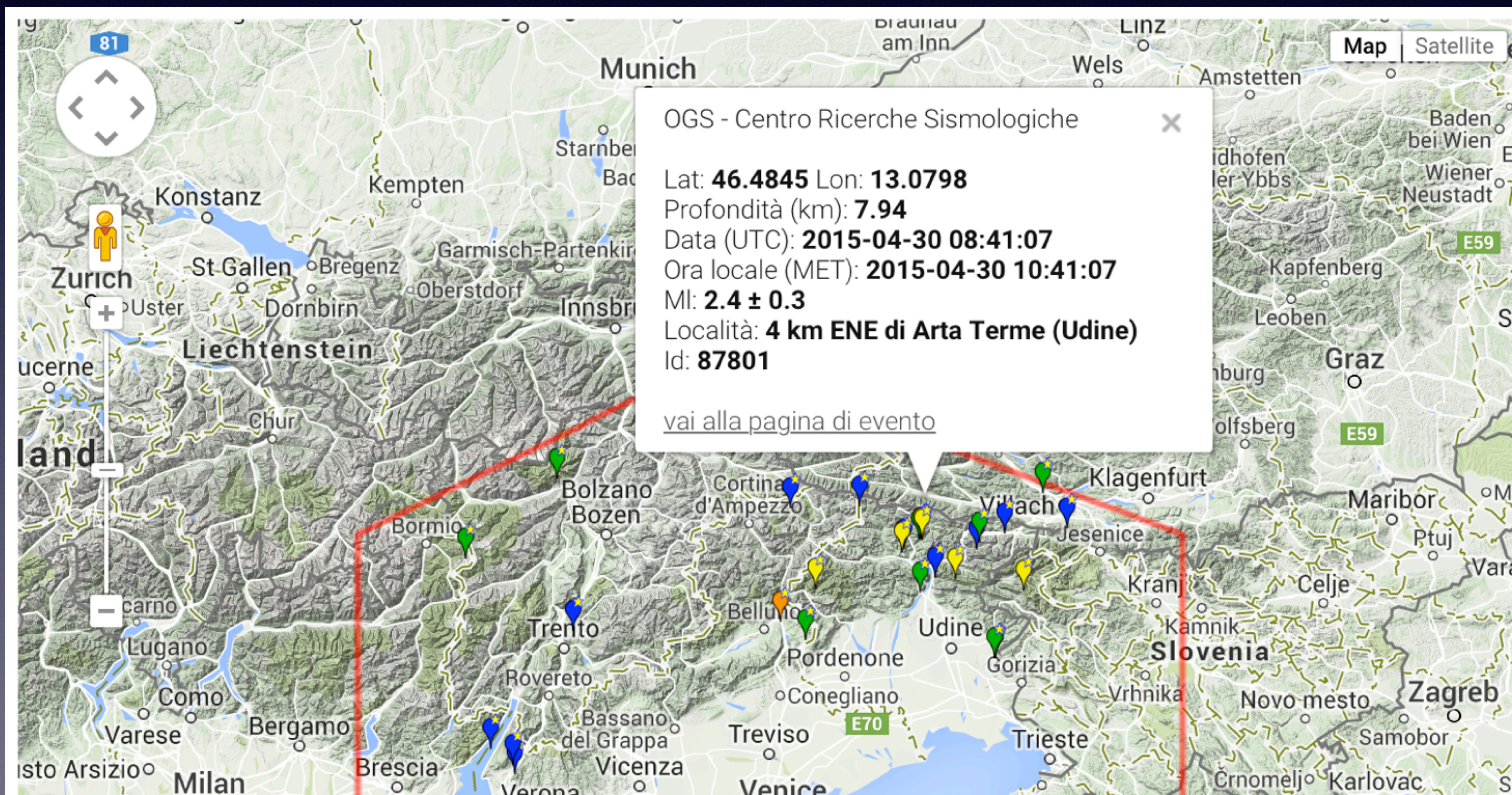
Earthquakes april-may 2015



The seismic monitoring
Seismic local network

www.crs.inogs.it

Monthly bulletin, news, info on seismic important events….etc.