Seismic hazard and environmental impact of earthquakes

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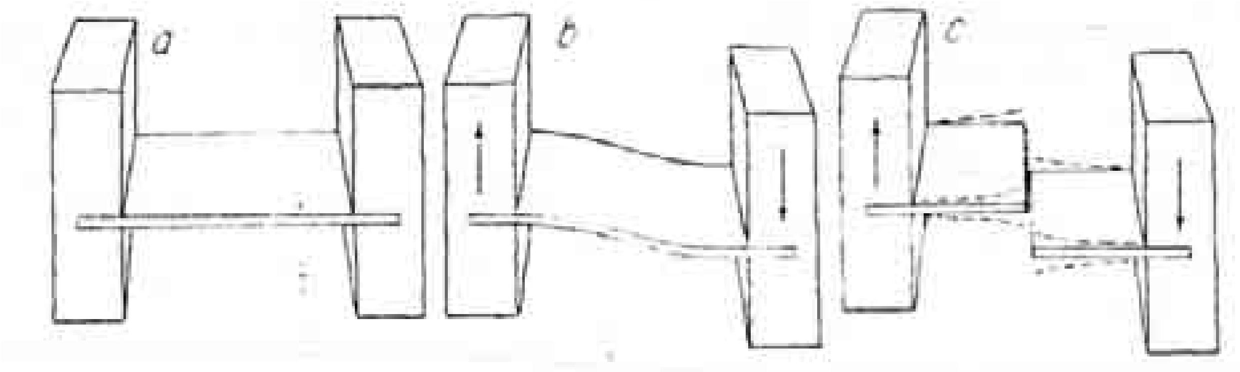
APAT

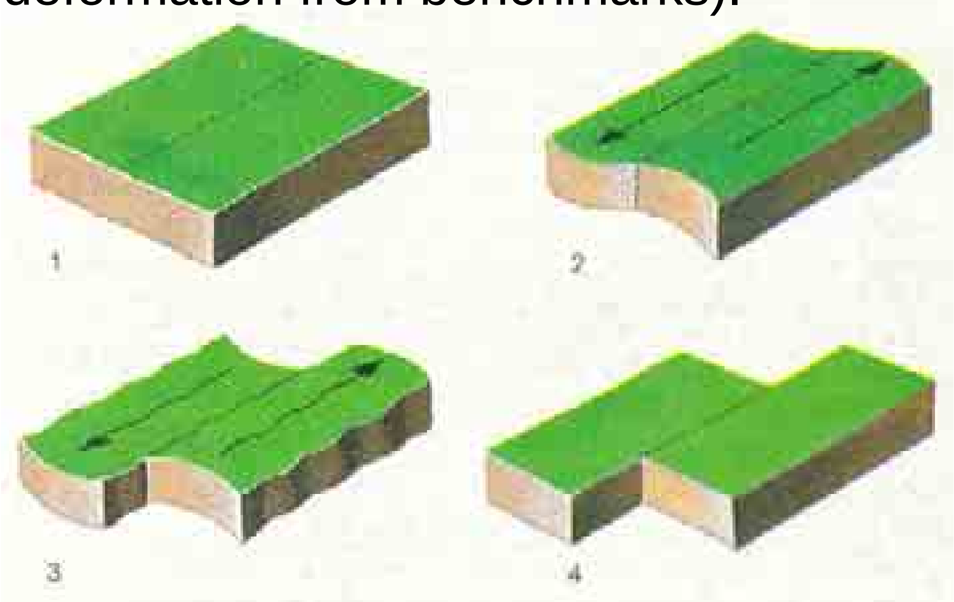
Agency for Environmental Protection and Technical Services



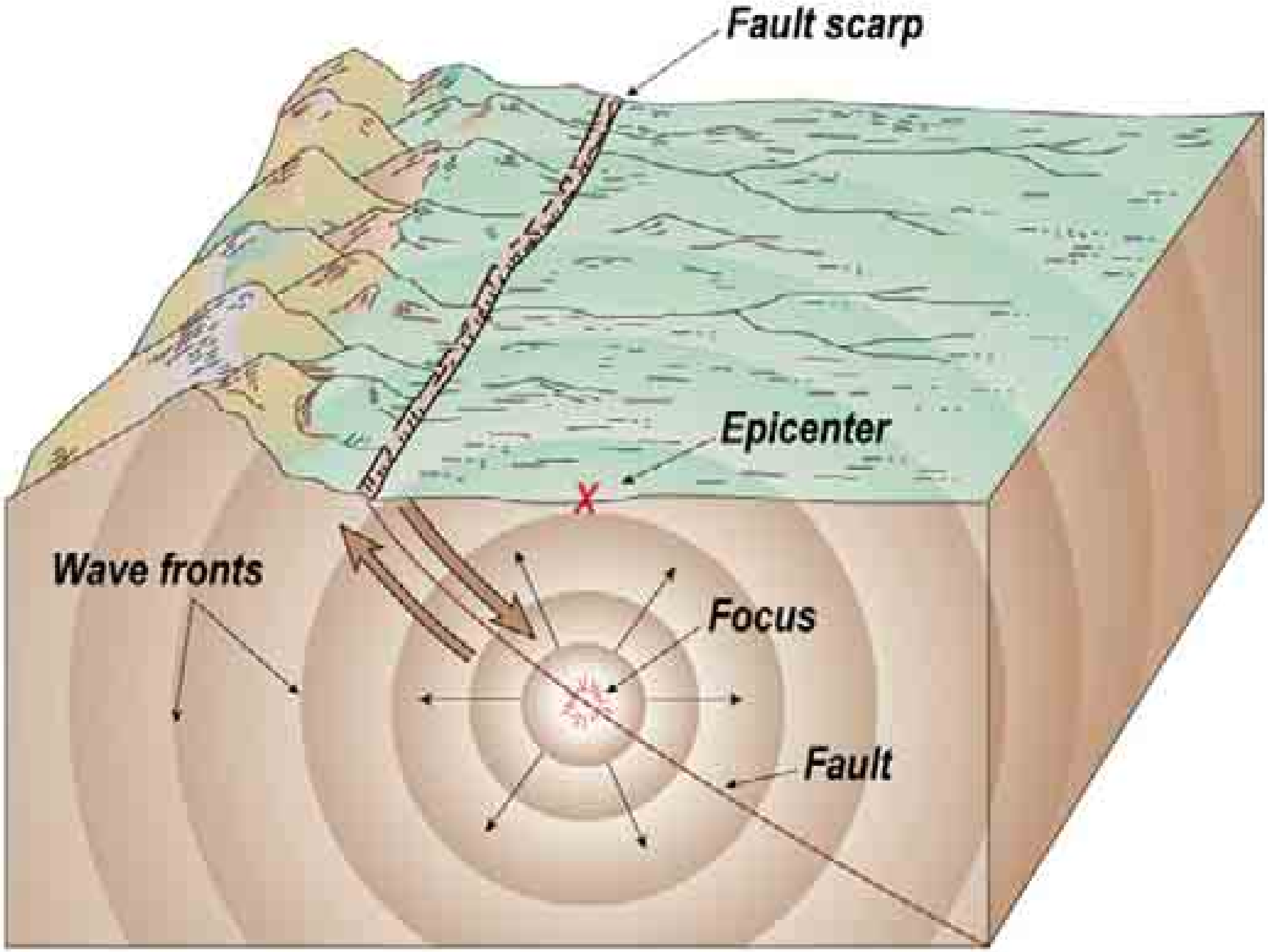
Nature and origin of earthquakes:

Elastic rebound model

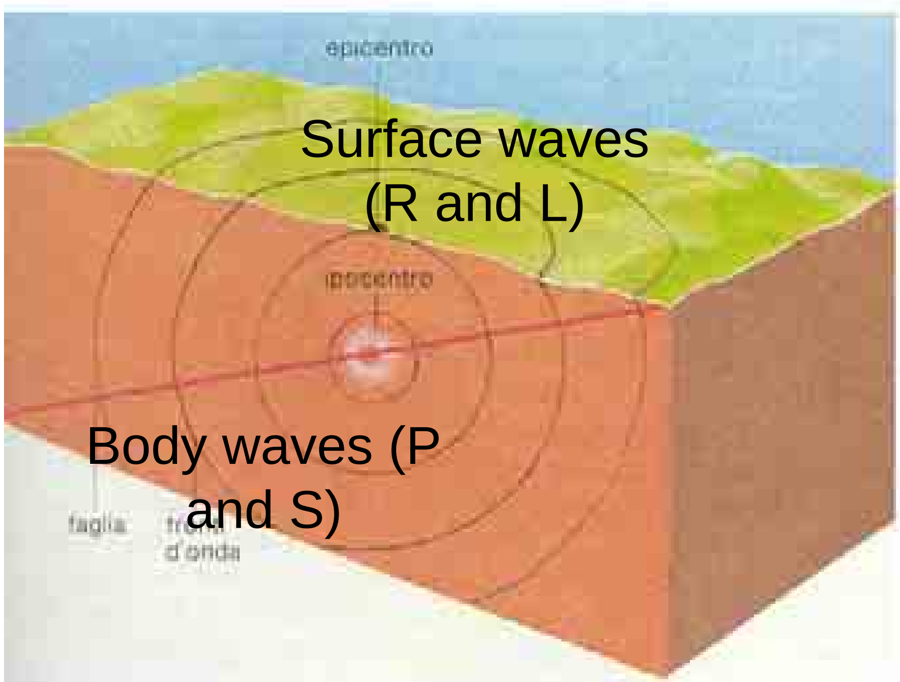
Theory by H.F. Reid to explain the origin of the San Francisco eq. In 1906 (ground deformation from benchmarks).

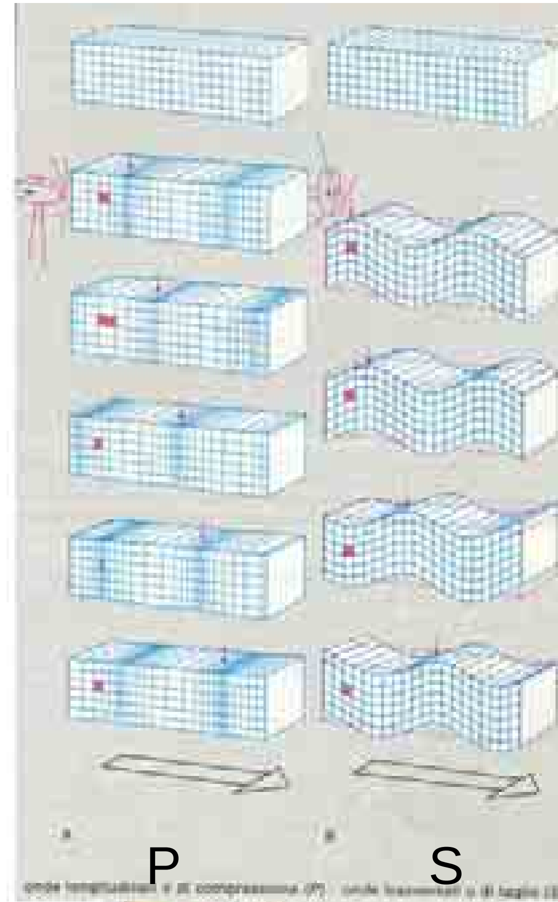


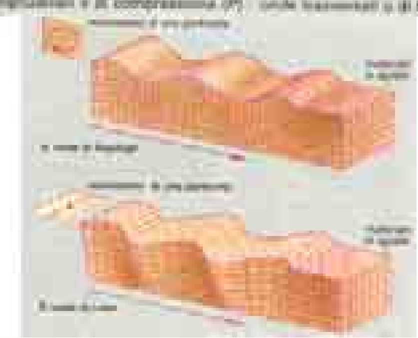
Fault slip and wave propagation



Fault slip and wave propagation







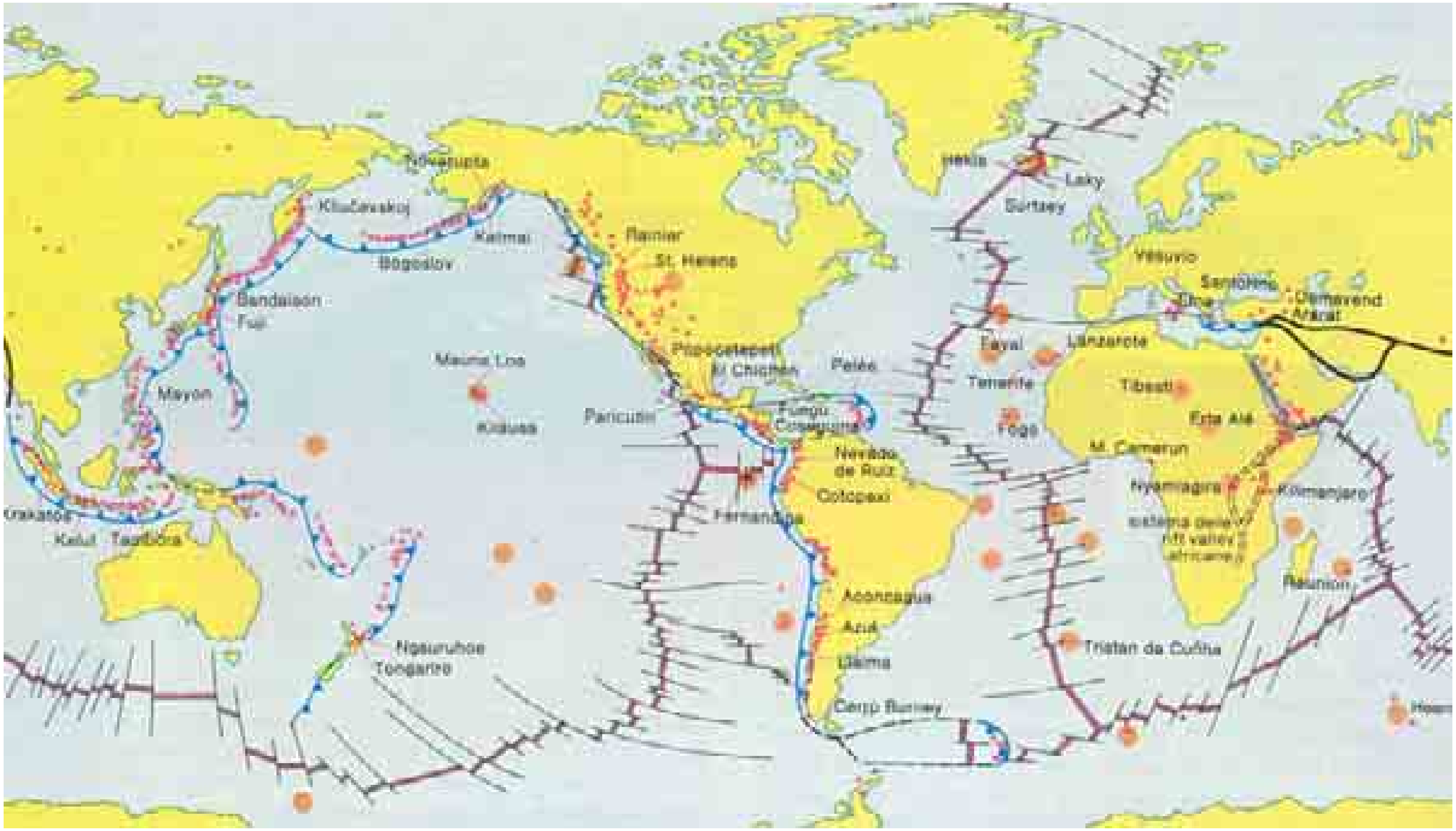
hypocentre → Compression waves (P): 4-8 km/s
→ Shear waves (S): 2,3-4,6 km/s

epicentre → Rayleigh (R): 2,7 km/s
→ Love waves (L): 3 km/s

Earthquake distribution

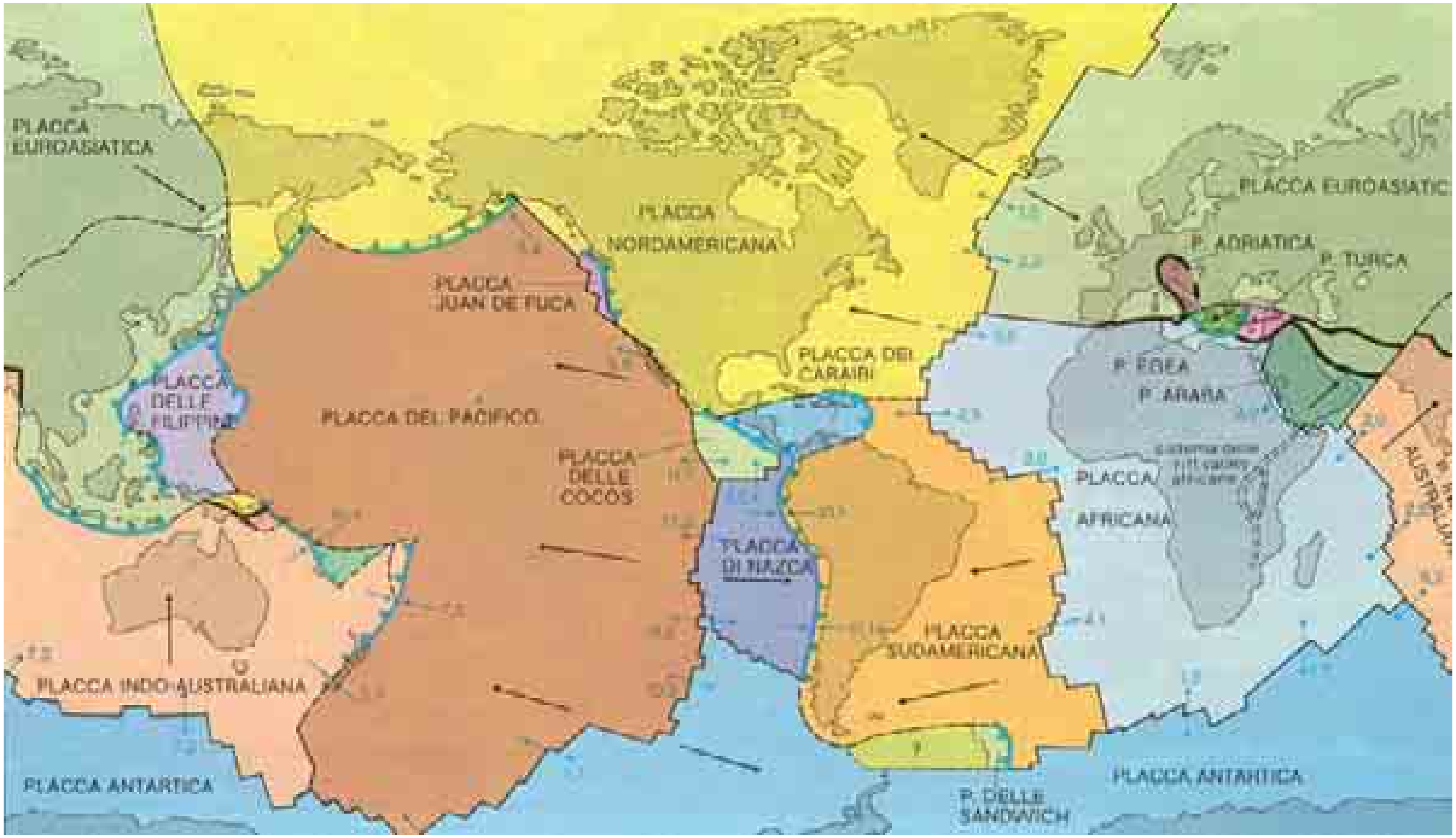
Epicentres of about 30,000 earthquakes registered during 1961-1967 (USGS)

Volcano distribution

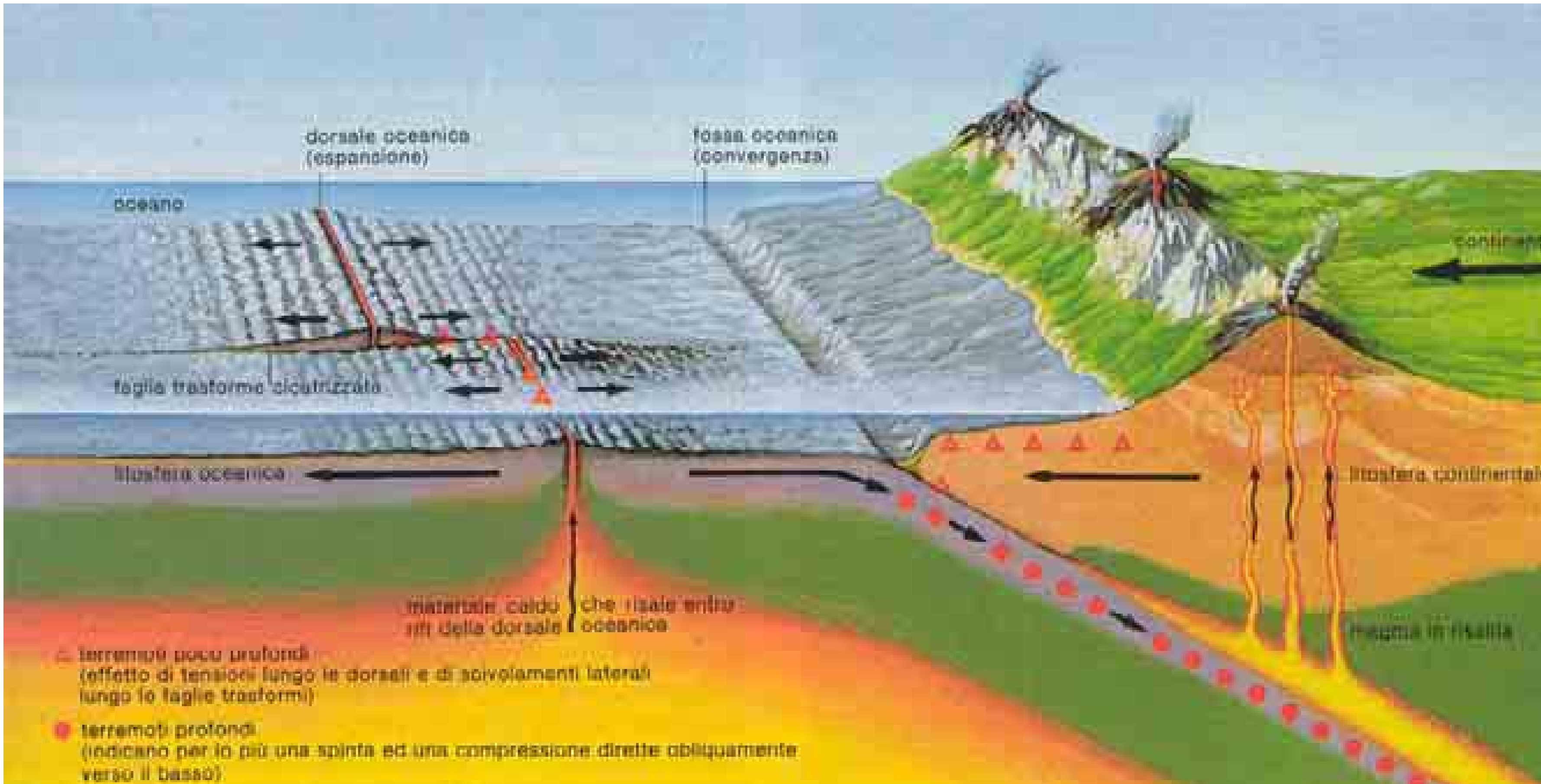


Distribution of over 500 active volcanoes, hot spots, subduction zones, oceanic troughs, faults, continental collisions

Plate tectonics



Lithosphere in motion



Relevance of earthquakes

Victims in the world in the last 1,000 years

3,000,000

Victims in the world from 1926 to 1950

350,000

Victims in Italy in the last 100 years

> 150,000 ?

Major Italian earthquakes in the last century

Date	Area	Intensity	Victims	wounded
1905	Calabria	X	557	2.000
1907	Calabria	IX	167	90
1908	Messina	XI	>100,000	many
1910	Irpinia	IX	50	many
1911	Monte Etna	X	13	48
1914	Monte Etna	X	69	115
1915	Fucino	XI	32,610	many
1917	Val Tiberina	IX-X	20	30
1919	Mugello	IX	100	400
1919	Monte Amiata	IX	1	20
1920	Lunigiana-Garfagnana	X	171	650
1928	Friuli	IX	11	40
1930	Irpinia	X	1,778	4264
1930	Anconetano	IX	18	several
1933	Maiella	IX	12	150
1936	Veneto-Friuli	IX	19	several
1962	Irpinia	IX	17	several
1968	Belice	X	231	623
1976	Friuli	IX-X	965	3000
1980	Irpinia-Basilicata	IX-X	2,914	10000

(source SSN)

Major earthquakes of the last century

San Francisco 1906, M= 7.8 750 victims

(source SSN)

Major earthquakes of the last century

(fonte SSN)

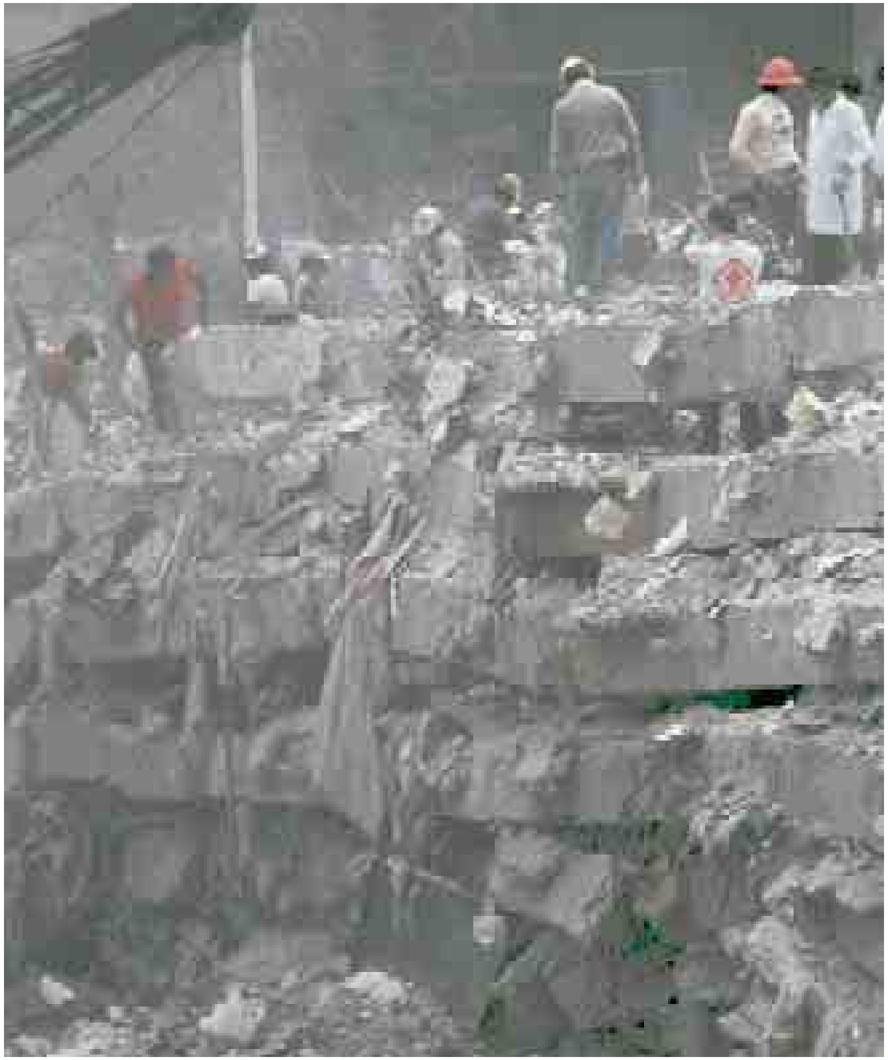
Reggio Calabria and Messina 1908, M= 7.2 >100,000 casualties ?

Major earthquakes of the last century

Alaska 1964, M= 8.4 136 casualties

Major earthquakes of the last century

Mexico 1985, M= 7.0 >10,000 casualties



Major earthquakes of the last century

Kobe 1995, M= 7.2 5,500 casualties

Seismic risk

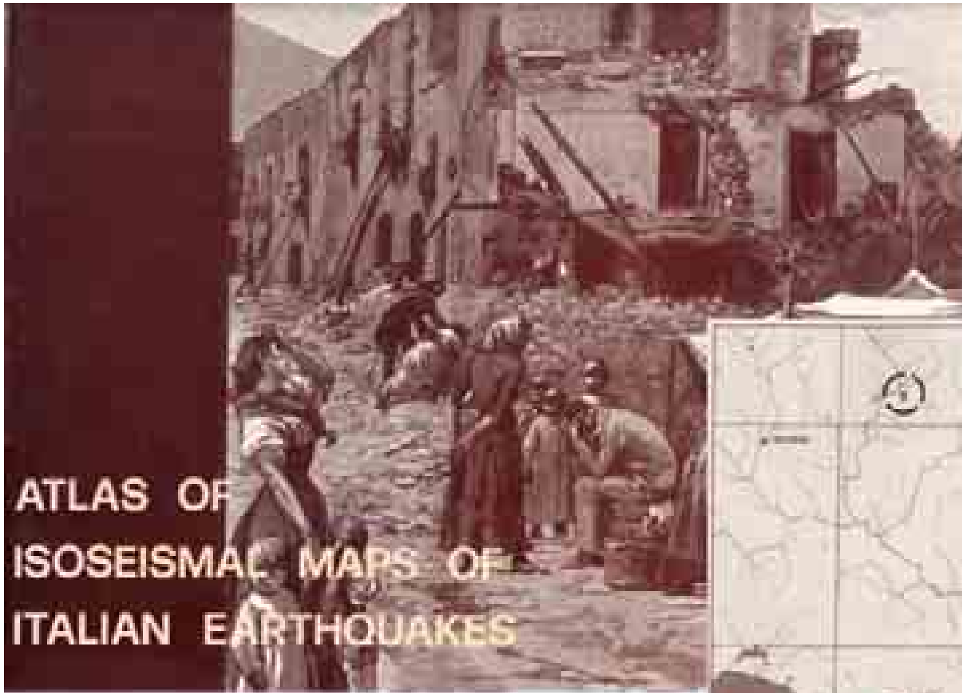
$$R = V * E * P$$

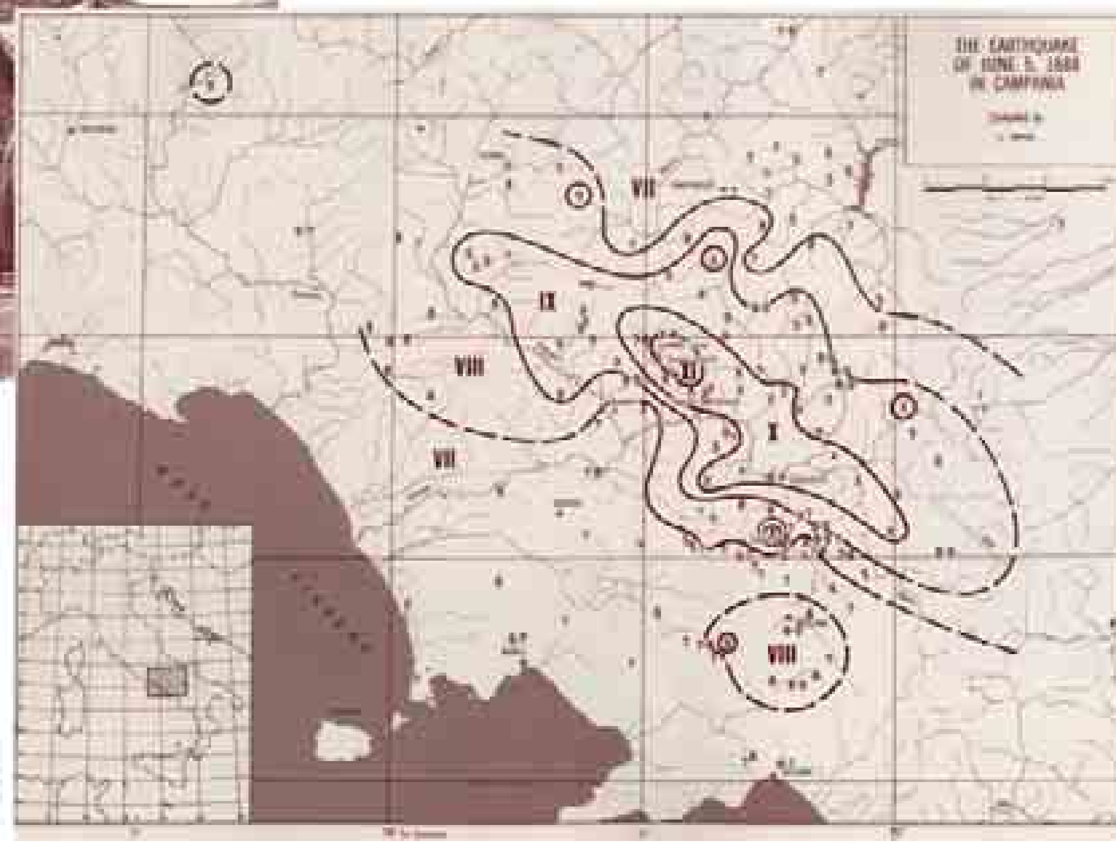
V = Vulnerability: attitude of goods at a site to suffer a certain level of damage due to a given level of shaking

E = Exposition: economic value of the goods and their use

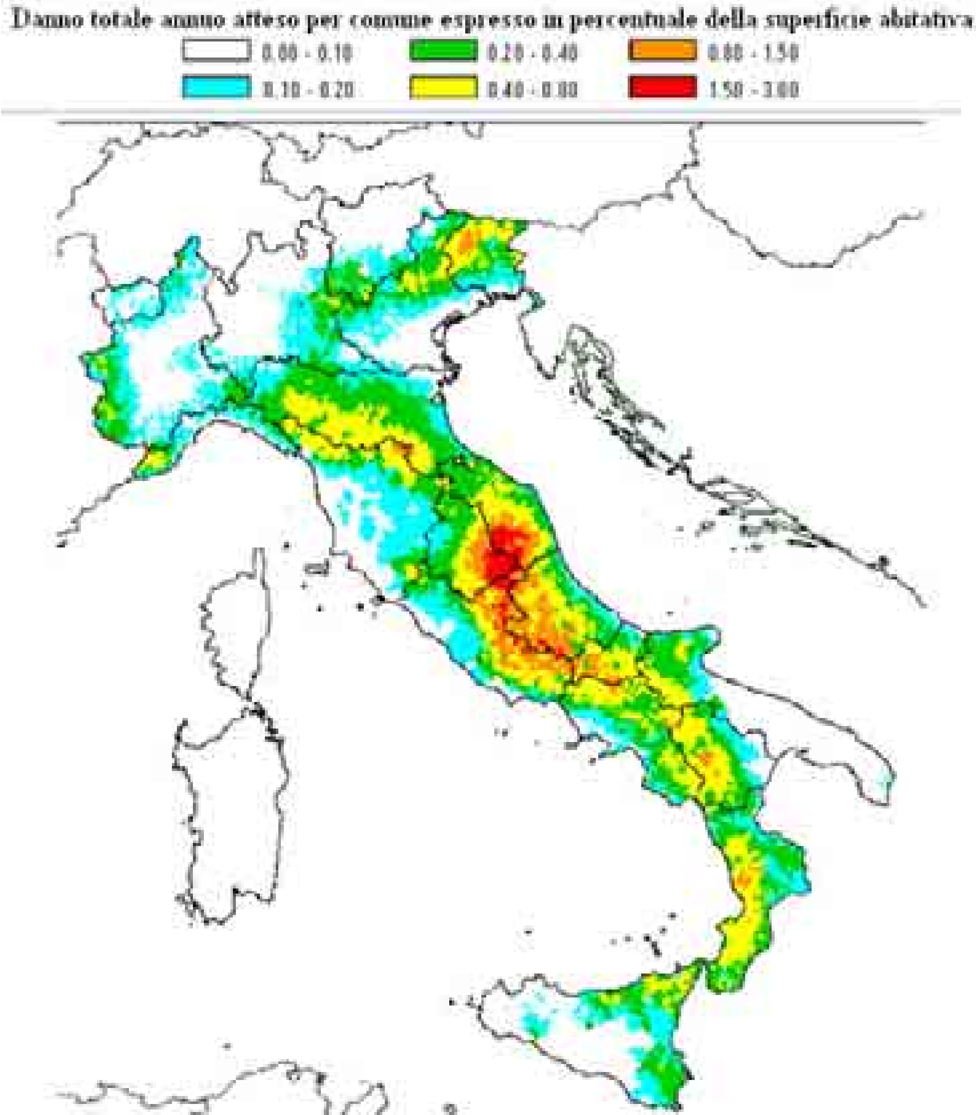
P = Seismic *Hazard*: probability to exceed a given level of shaking at a site whitin a given time span

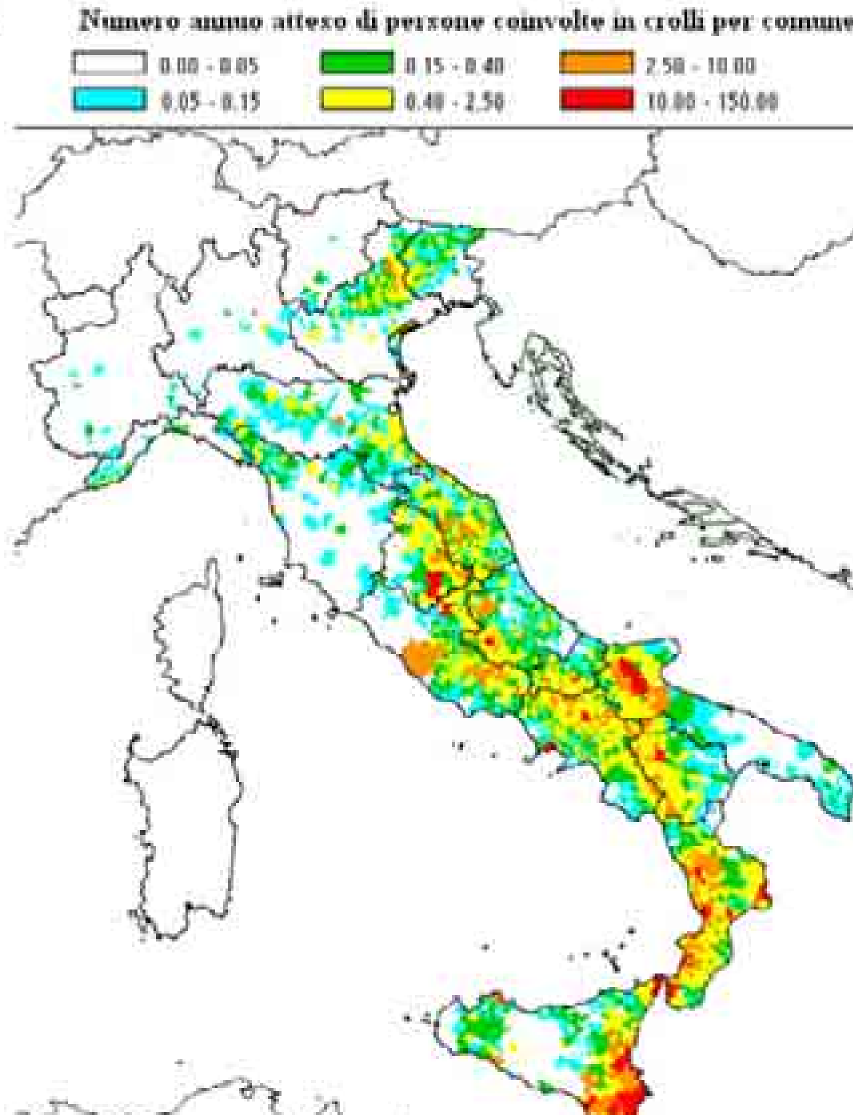
The hazard depends solely on the natural phenomen (more in general a hazard is any source of potential damage)
the risk is the likelihood of harm due to a hazard and depends on human variables. The hazard is fixed, but risk can be mitigated.





Sannio earthquake 1688





Servizio Sismico Nazionale http://www.serviziosismico.it/PROG/G_RISCHI/PERDANTOT/perdantot_f.html

The most dramatic seismic sequence in Italy

1676 to have another IX intensity at least

1688 -April, 11	Romagna	**IX**
1688 -May, 31	Fano	**VIII**
1688 -June, 5	Benevento	**XI**
1690 -December, 4	Villaco Venezia	**VIII -IX**
1690 -December, 23	Ancona	**VIII**
1692 –October, 24	Fano	**VIII**
1693- January, 11	Vai di Noto	**XI**
1694 -September, 8	Avellino -Basilicata	**XI**
1695 February, 25	Asolo	**X**
1695 -June, 11	Bagnoregio	**IX**
1700 -July, 28	Carnia	**VIII**
1702- March, 14	Benevento	**X**
1703 -January, 14	Norcia	**X -XI**
1703 -January, 16	Montereale	**XI**
1703 -February, 2	L'Aquila	**XI**
1706 -November, 3	MaieJla	**XI**

1717 to have another IX intensity at least

How do we measure earthquakes ?

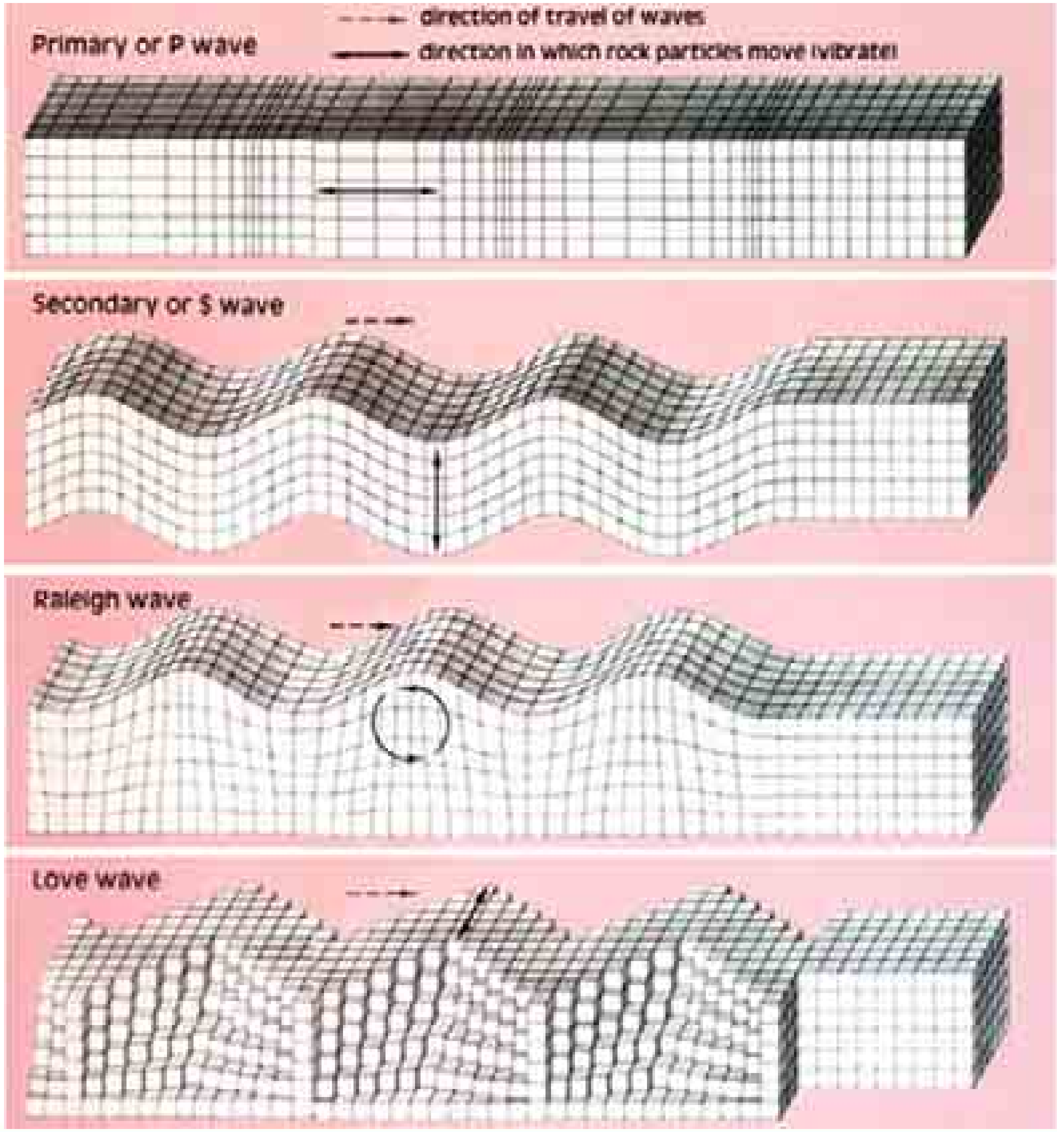
Magnitude
(instrumental data)

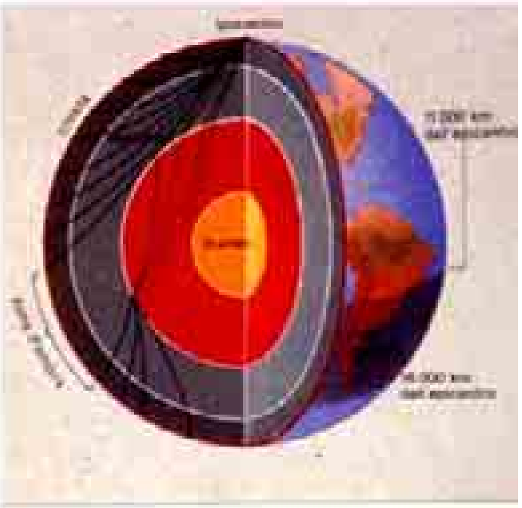
Ground motion

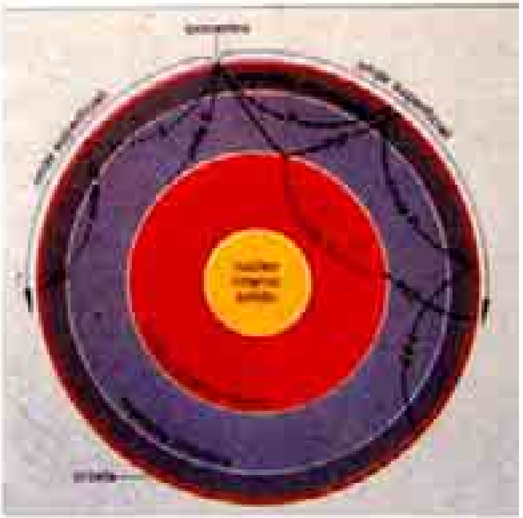
Intensity
(macroseismic data)

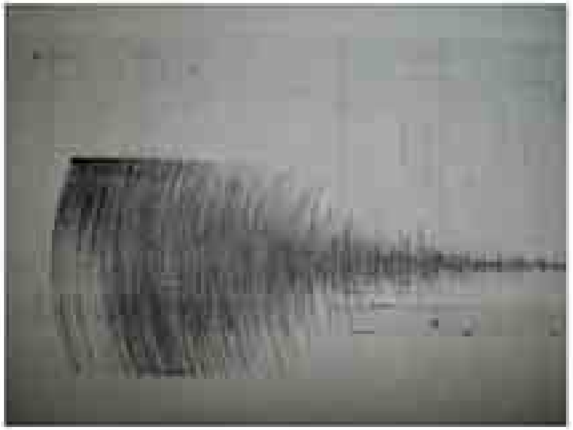
Effects on environment, man and structures

Wave propagation

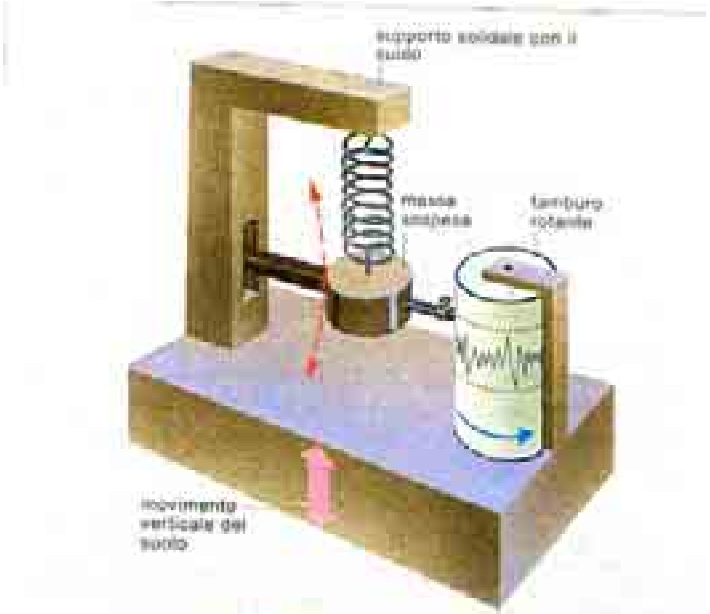


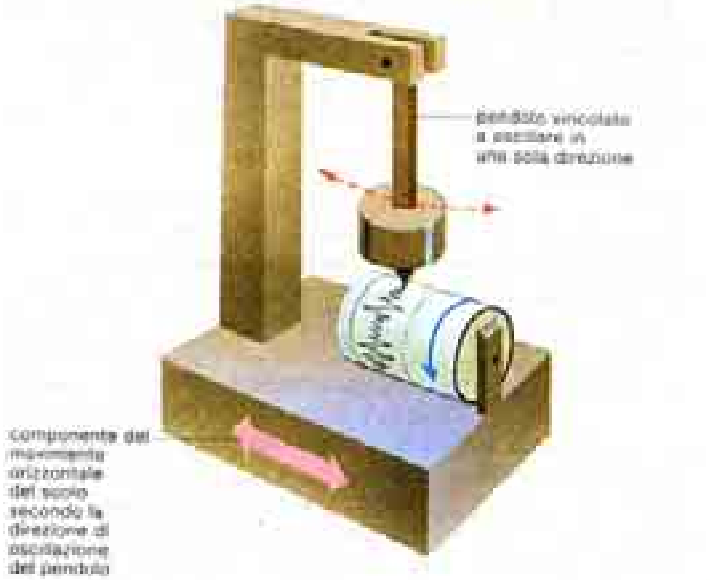




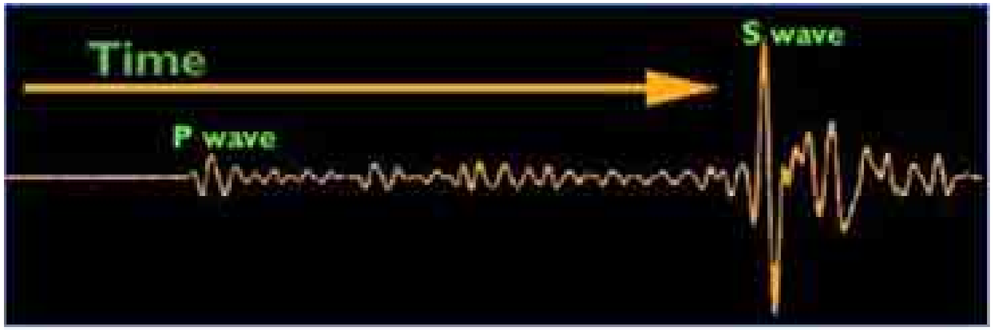


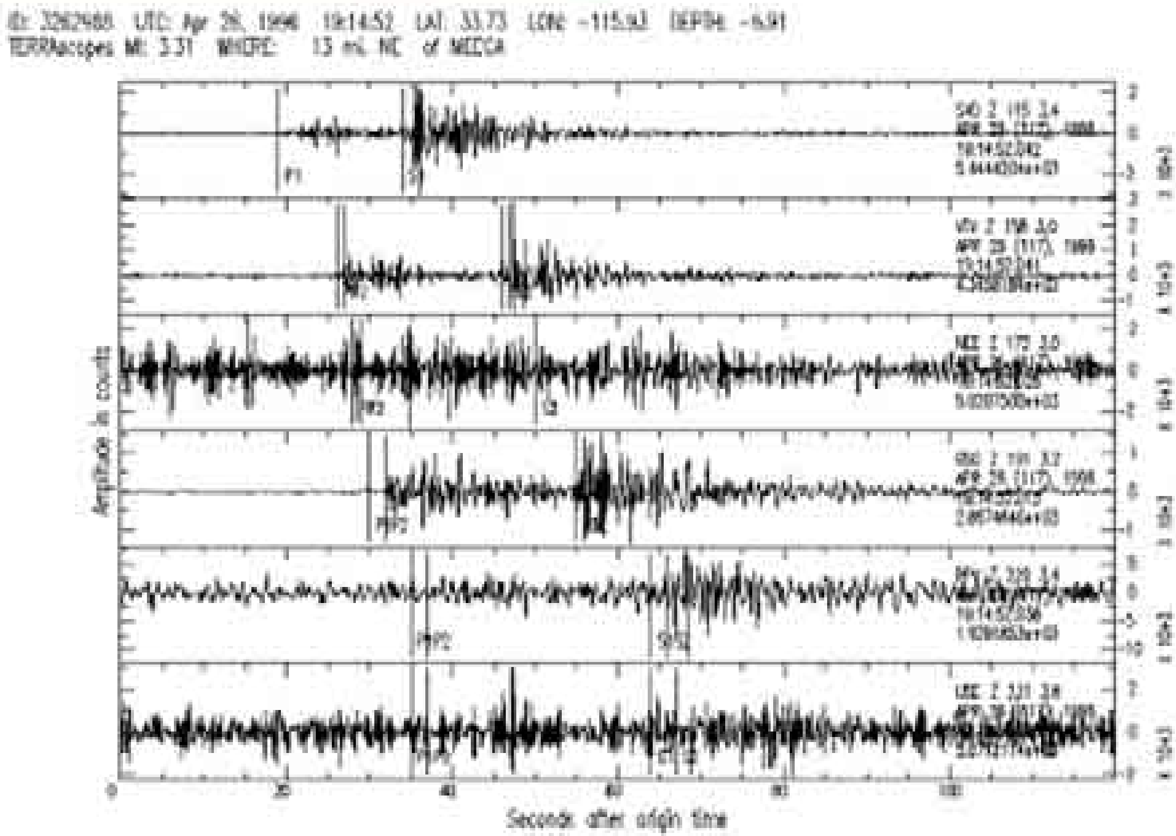
Seismograph





Seismograms



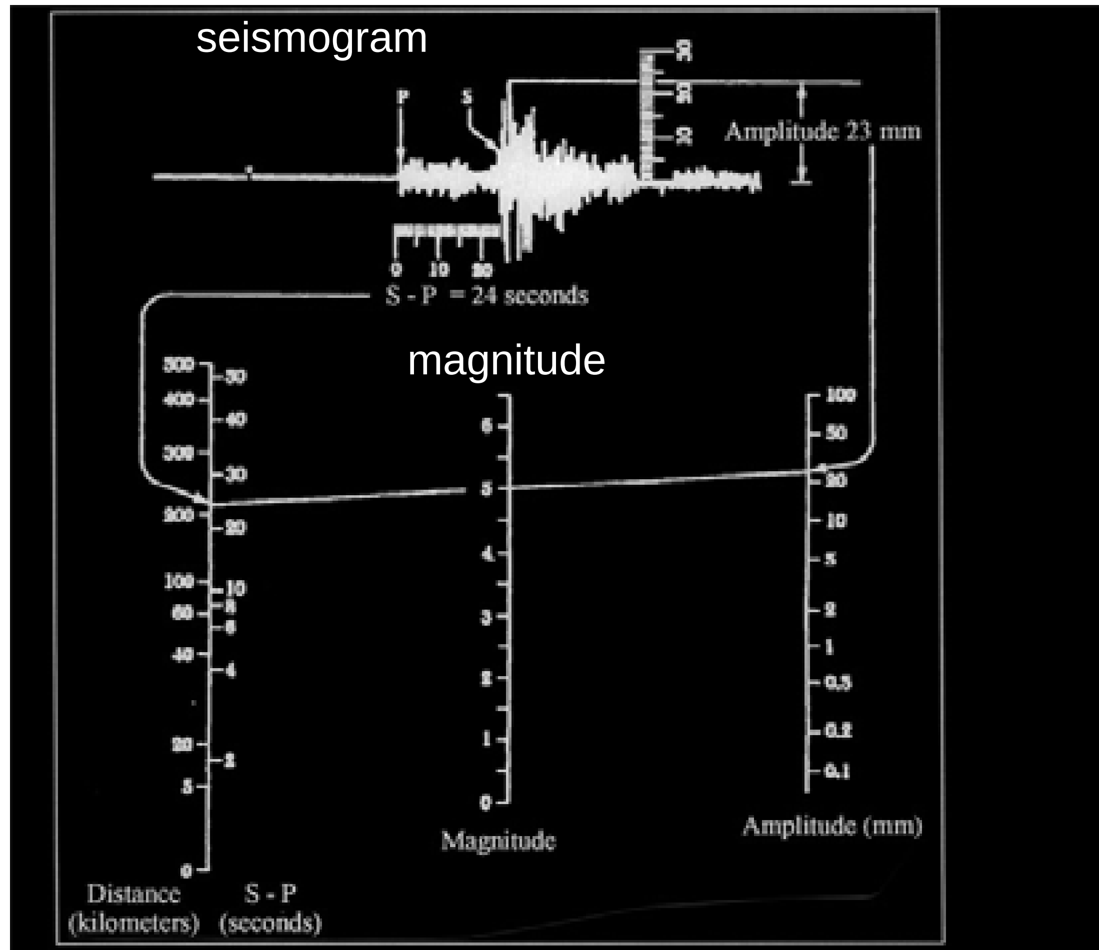


Magnitude “Richter” (1935)

Reference seismic station
(at 100 km from epicentre)
Reference earthquake: M=1
Oscillation amplitude: 0,001 mm

$$M=\log_{10}\frac{\text{Amplitude registered oscillation}}{\text{Amplitude reference oscillation}}$$

Seismic station at 100 km from epicentre



Determination of Richter Magnitude (Ml) for a local earthquake (from Bolt, 1978 Earthquakes Freeman & Co. San Francisco)

Magnitude Richter (logarithmic scale)
Amplitude of motion

Earthquake Magnitude Classes

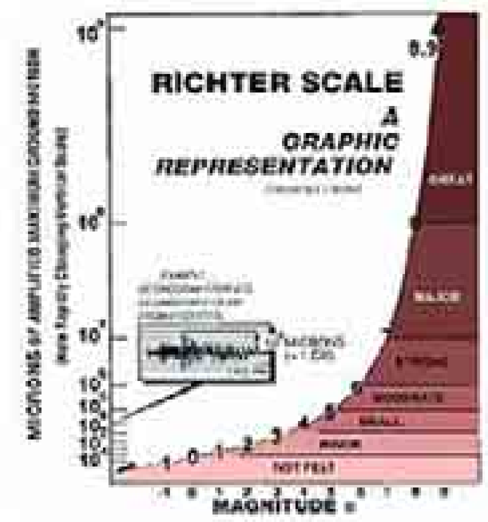
Magnitude	Earthquake Effects	Estimated Number Each Year
2.5 or less	Usually not felt, but can be recorded by seismograph.	900,000
2.5 to 5.4	Often felt, but only causes minor damage.	30,000
5.5 to 6.0	Slight damage to buildings and other structures.	500
6.1 to 6.9	May cause a lot of damage in very populated areas.	100
7.0 to 7.9	Major earthquake. Serious damage.	20
8.0 or greater	Great earthquake. Can totally destroy communities near the epicenter.	One every 5 to 10 years

Table 1: COMPARISON OF RICHTER MAGNITUDE AND MODIFIED MERCALLI INTENSITY

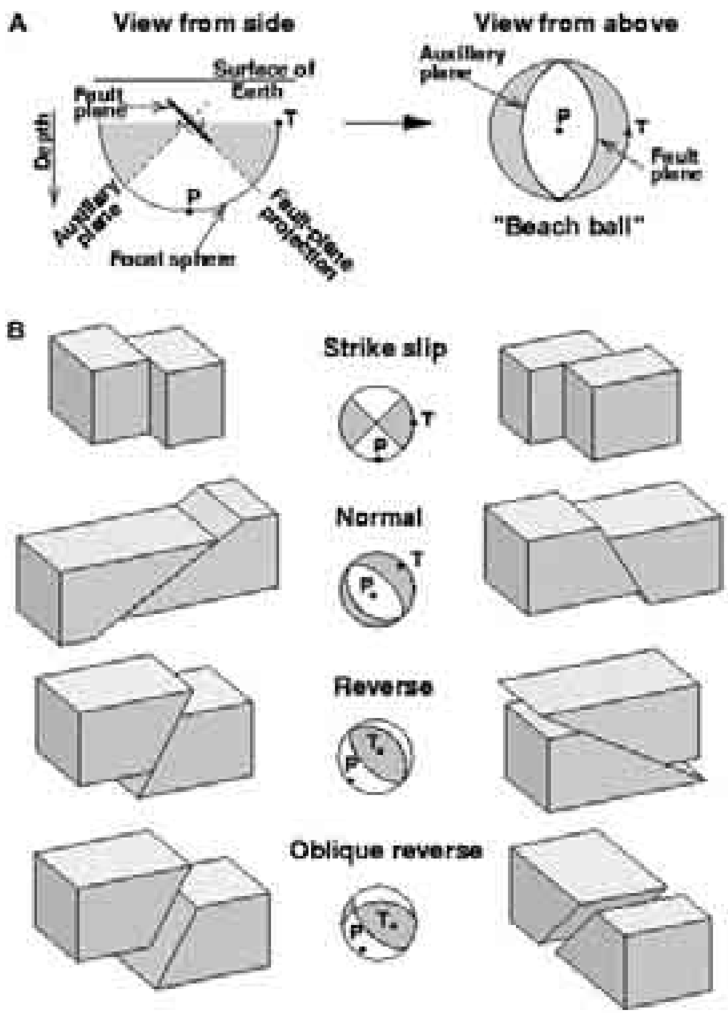
Richter Magnitude		Expected Modified Mercalli Maximum Intensity (at epicenter)
2	I-II	Usually detected only by instruments
3	III	Felt indoors
4	IV-V	Felt by most people; slight damage
5	VI-VII	Felt by all; many frightened and run outdoors; damage minor to moderate
6	VII-VIII	Everybody runs outdoors; damage moderate to major
7	IX-X	Major damage
8+	X-XI	Total and major damage

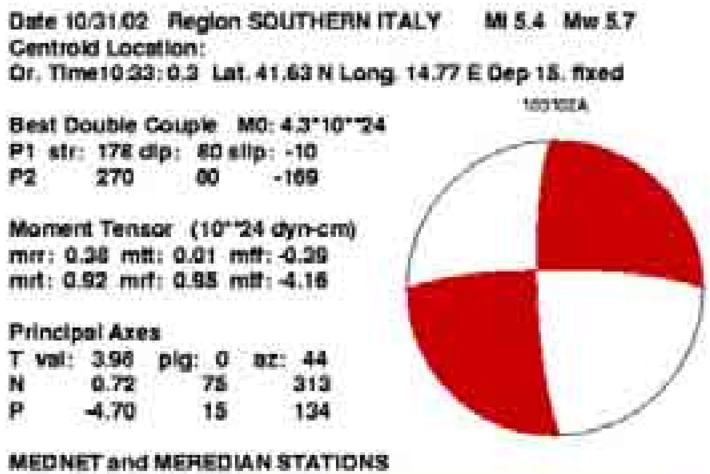
After Charles F. Richter, 1958, *Elementary Seismology*.

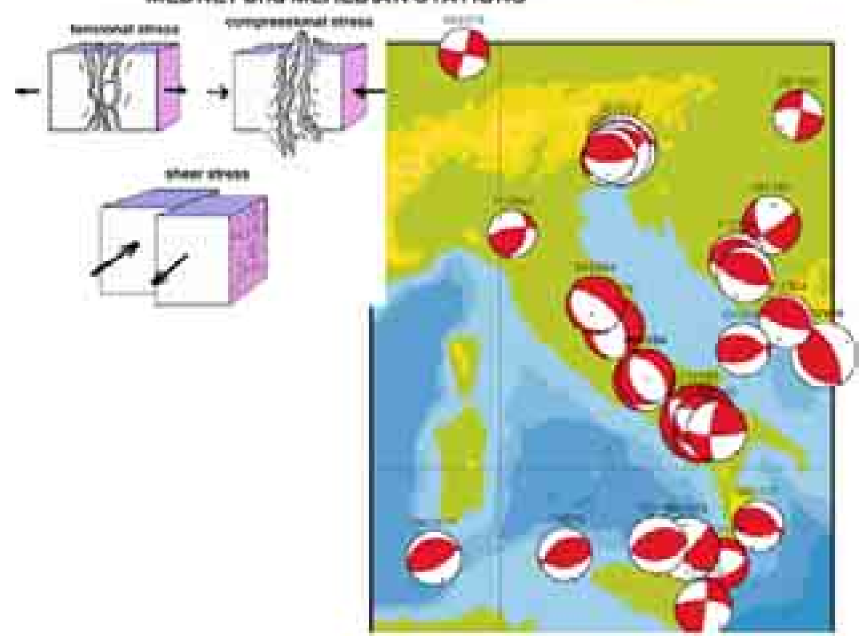
Class	Magnitude
Great	8 or more
Major	7 - 7.9
Strong	6 - 6.9
Moderate	5 - 5.9
Light	4 - 4.9
Minor	3 -3.9

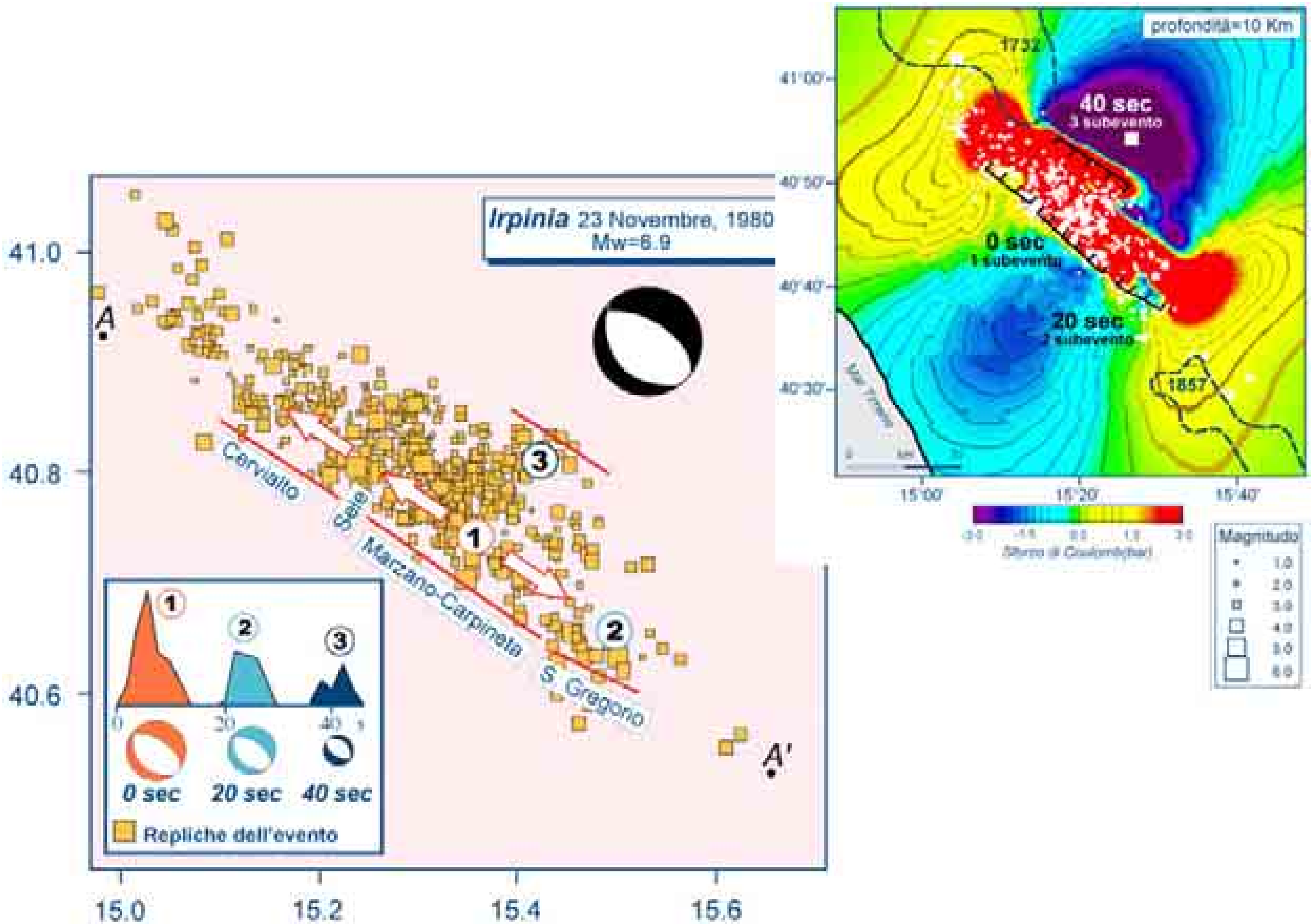


Focal mechanism

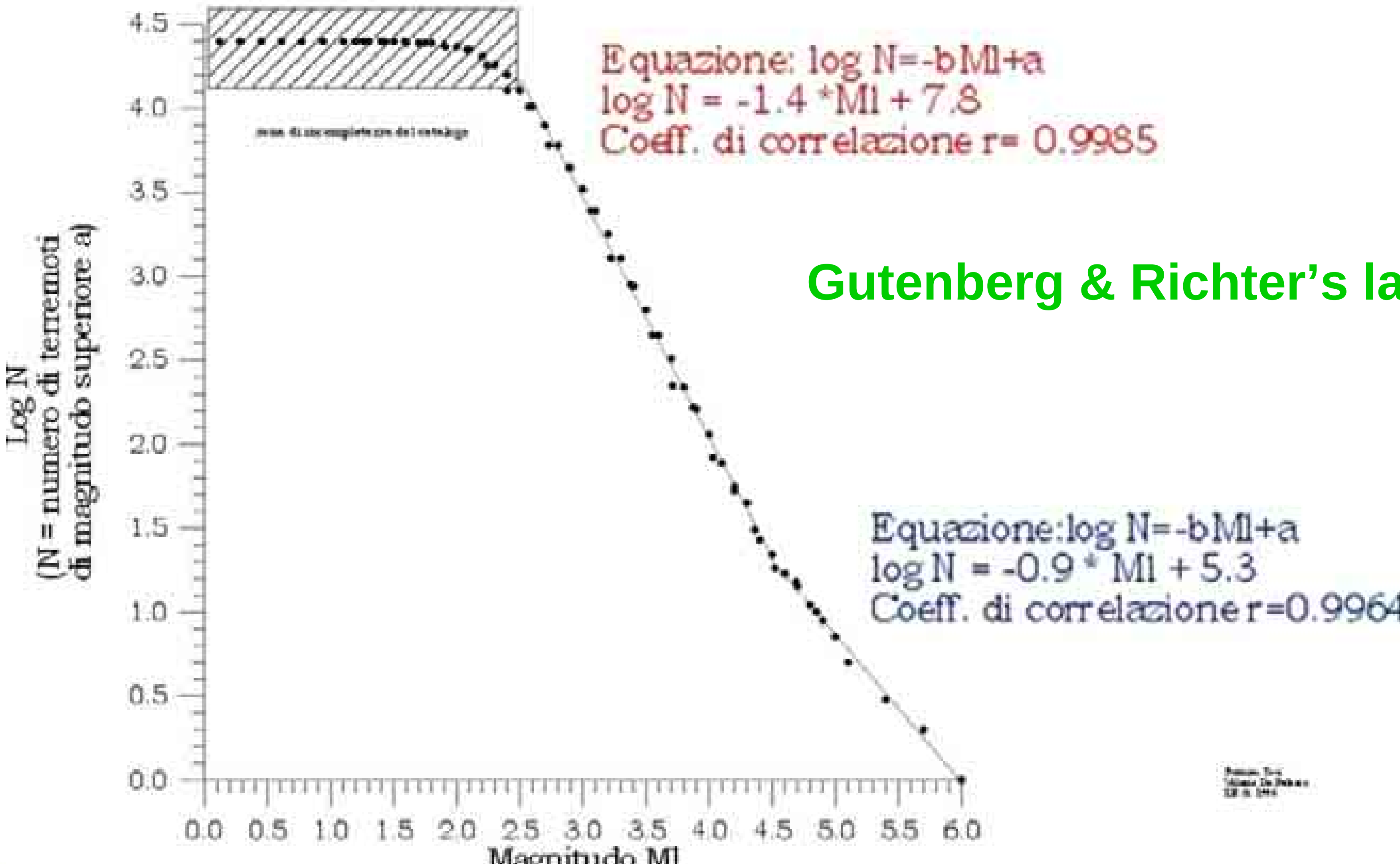







Irpinia 23 Novembre, 1980
Mw=6.9
41.0
40.8
40.6
15.0
15.2
15.4
15.6
A
A'
Cervialto
Sele
Marzano-Carpineta
S. Gregorio
1
2
3
0 sec
20 sec
40 sec
Repliche dell'evento
profondità=10 Km
1732
1857
40 sec
3 subevento
0 sec
1 subevento
20 sec
2 subevento
41°00'
40°50'
40°40'
40°30'
15°00'
15°20'
15°40'
Magnitudo

Distribuzione cumulata degli eventi sismici in funzione della magnitudo dal 1 gen. 1983 al 5 ott. 1997 (Regione italiana)



Gutenberg & Richter's law

How do we locate an earthquake ?

Ground motion

Dromocrones

Effects on environment, man and structures

Intensity

Instrumental location

Dromocrones

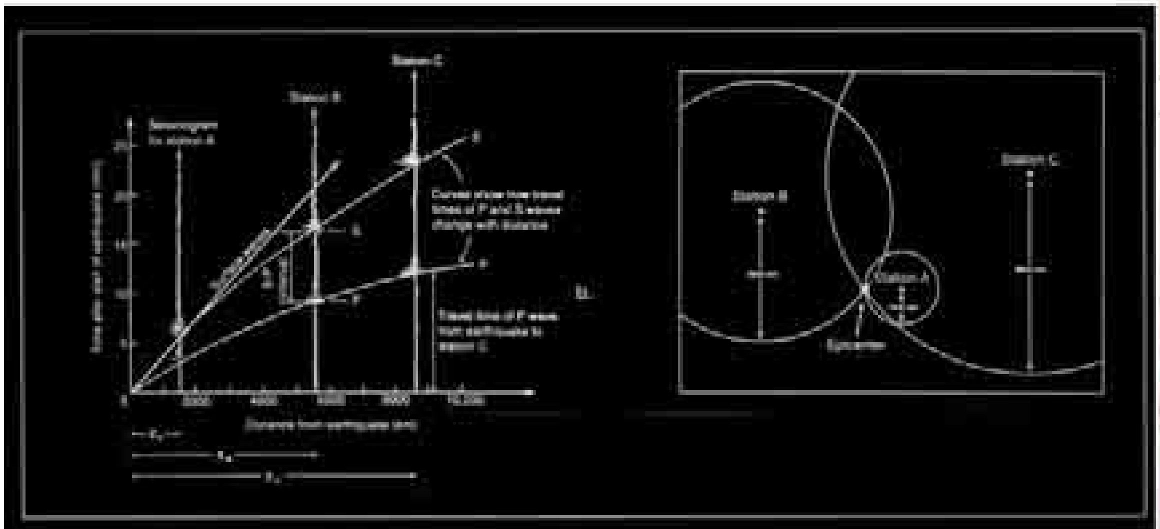
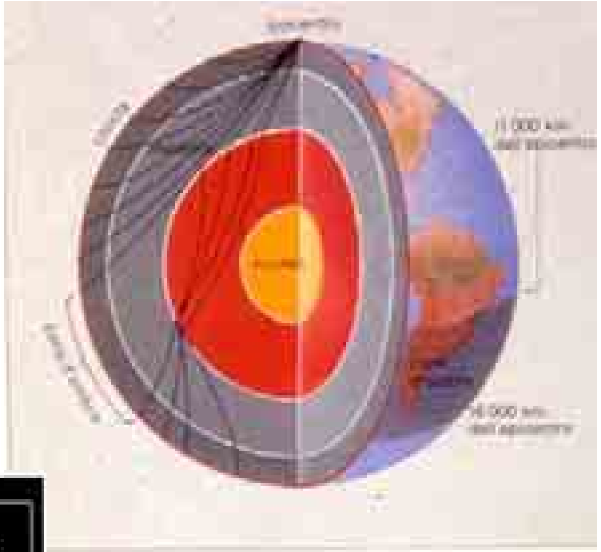
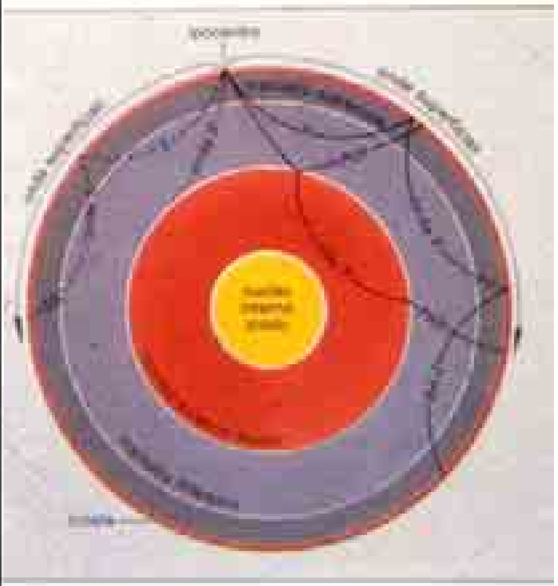
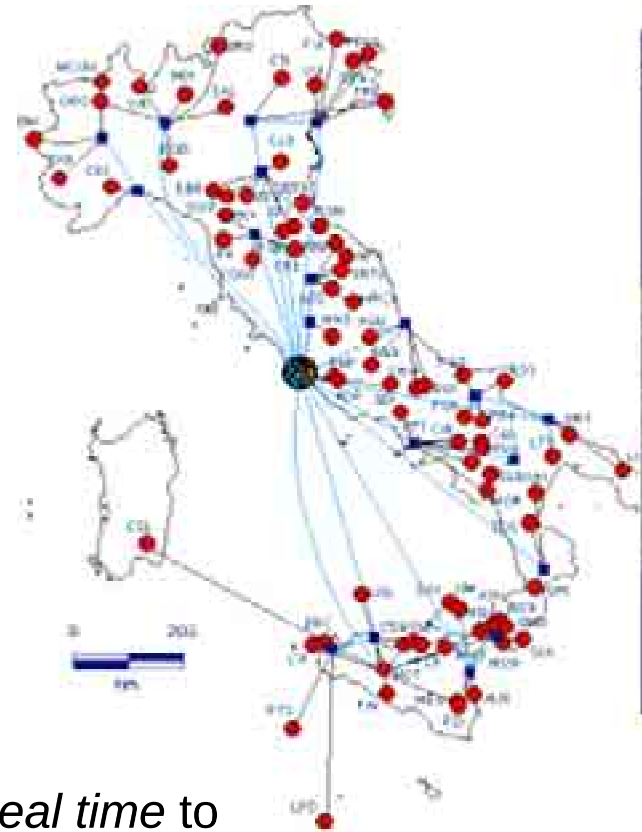


Fig. 2.6 : a) Seismograms of the same earthquake as recorded by seismographs located at A, B and C. The time interval between the passage of the P wave and the S wave allows the calculation of the distance between the seismographs and the earthquake, because the speeds of P waves and the S waves are known. b) This is shown on a map as the radius of a circle with the seismograph at the center. The earthquake is located where the three circles intersect (from Yeats et al., 1997).





Italian seismometric network



Instruments:
- Short period 1 sec
- Large band > 20 sec

- Analogic
- Digital
- 1 or 3 components
- transmission *real time* or *near real time* to operation room in radiofrequency, dedicated telephone lines, satellite and internet.

INGV

Seismometric station

17/mar/98. Est. Canario. (Foto: R. Quaas) e0317982.jpg

27/nov/97. Estación Canario. Popocatépetl. (Foto R. Quaas) e1127971.jpg

How do we measure earthquakes ?

Magnitude
(instrumental data)

Ground motion

Intensity
(macroseismic data)

Effects on environment, man and structures

Intensity

Effects on man, structures, environment

Scale MCS
Mercalli – Cancani – Sieberg (1930)

I - Sisma non percepito dall'uomo; registrato solo dai sismografi.

II - Percepito ai piani alti delle case (i quali oscillano più dei piani a terra) da persone sensibili.

III - Percepito da più persone, oscillazione di oggetti appesi e vibrazioni.

IV - Oscillazioni e vibrazioni anche di automezzi, tintinnio di vetri, vibrazioni di vasellame, scricchiolio di pareti.

V - Scossa che sveglia chi dorme, scricchiolii, tintinnii, spavento; cadono calcinacci.

VI - Fa fuggire le persone all'aperto, produce rumori e boati, fa cadere oggetti pesanti, provoca qualche lesione agli edifici.

VII - Provoca panico, caduta di intonachi, camini e tegole, rottura di vetri, danni di scarsa entità ai muri, piccole frane in materiali sciolti, suono di campane, onde sugli specchi d'acqua.

VIII - Si sente anche guidando automezzi, danneggia murature anche buone ma non di cemento armato; provoca la caduta di torri, palizzate, alberi e l'apertura di crepacci nel suolo.

IX - Distrugge edifici non particolarmente resistenti, rompe tubazioni sotterranee, provoca ampi crepacci nel terreno, apre crateri con espulsione di sabbia e fango.

X - Distrugge buona parte degli edifici, danneggia dighe ed argini, devia fiumi e rotaie, provoca grandi frane, sposta orizzontalmente i terreni che si sono fessurati.

XI - Rovina completamente gli edifici, rompe ogni tubazione, tronca le comunicazioni, provoca un gran numero di vittime.

XII - Distrugge ogni opera umana, sposta grandi masse rocciose o vasti tratti di terreno in cui si aprono larghi crepacci, lancia in aria oggetti, provoca grandi frane e può causare migliaia di vittime.

I degree: **Pane, amore e gelosia (L. Comencini) 1954**

II degree: **Il diavolo alle quattro (M. Le Roy) 1961**

III degree: **The sisters (L. Comencini) 1938**

IV degree: **San Francisco (W. Van Dyke) 1936**

Cinema e terremoti

V degree: Terremoto
(M. Robson) 1975

VI degree: Flame of barbary coast
(J. Kane) 1945

VII degree: Sodoma e Gomorra
(R. Aldrich e S. Leone) 1962

VIII degree: Terremoto
(M. Robson) 1975

Cinema e terremoti

IX degree: The sisters (L. Comencini) 1938

X degree: Superman (R. Donner) 1978

XI degree: San Francisco (W. Van Dyke) 1936

XII degree: Fantasia (W. Disney) 1940

Carta del
Terremoto di San Severo, 1627

Intensity

Depends on:

<u>Natural factors</u>

magnitude

Hypocentral depth

Epicentral distance

duration

number and type of shakings

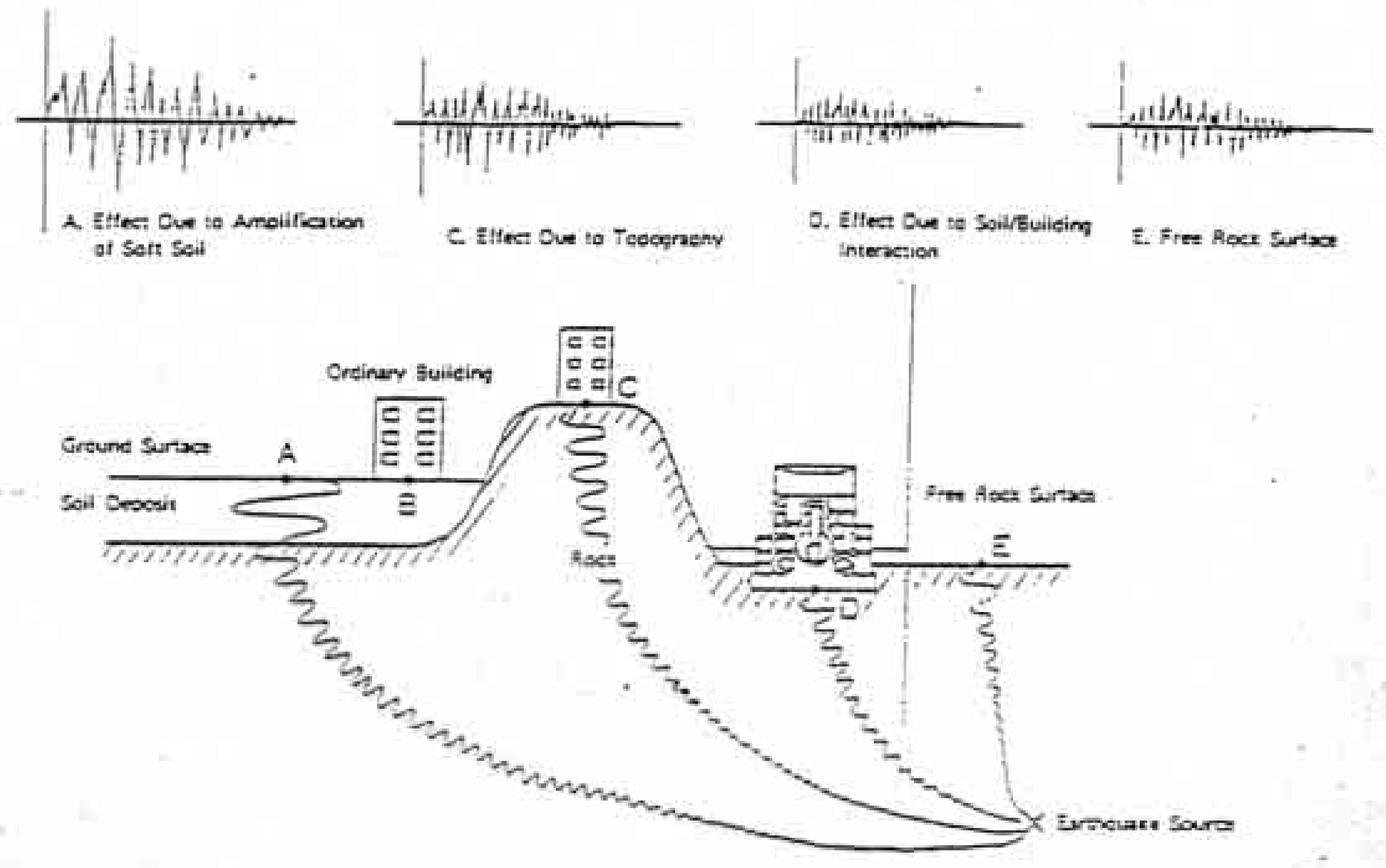
ground nature and morphology (local conditions)

<u>Human factors</u>

Type and shape of buildings and foundations ground nature and morphology (local conditions)

Intensity

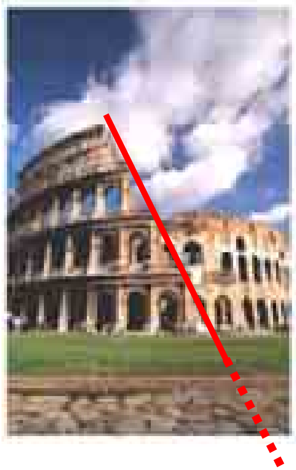
earthquake ground motions



ground nature and morphology (local conditions)

Intensity

Differential damages to Colosseum



Valle alluvionale recente (Olocene)

Valle alluvionale antica (Pleistocene medio)

A) Riporti (Olocene)

B) Alluvioni (Olocene)

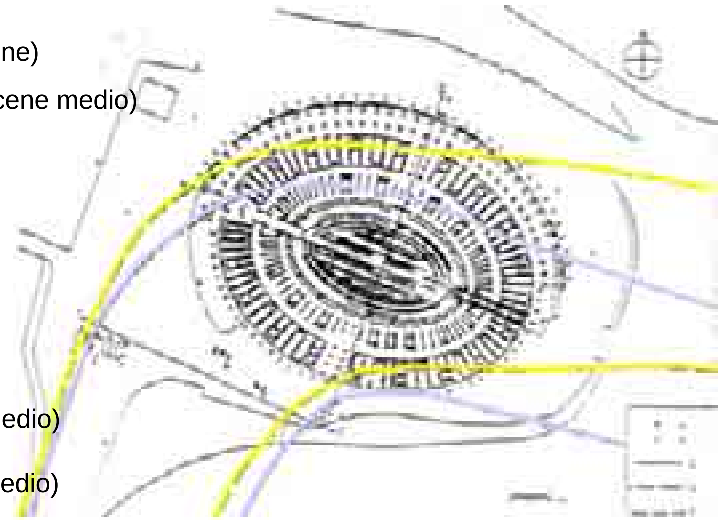
C) Unità Aurelia (Pleist. medio)

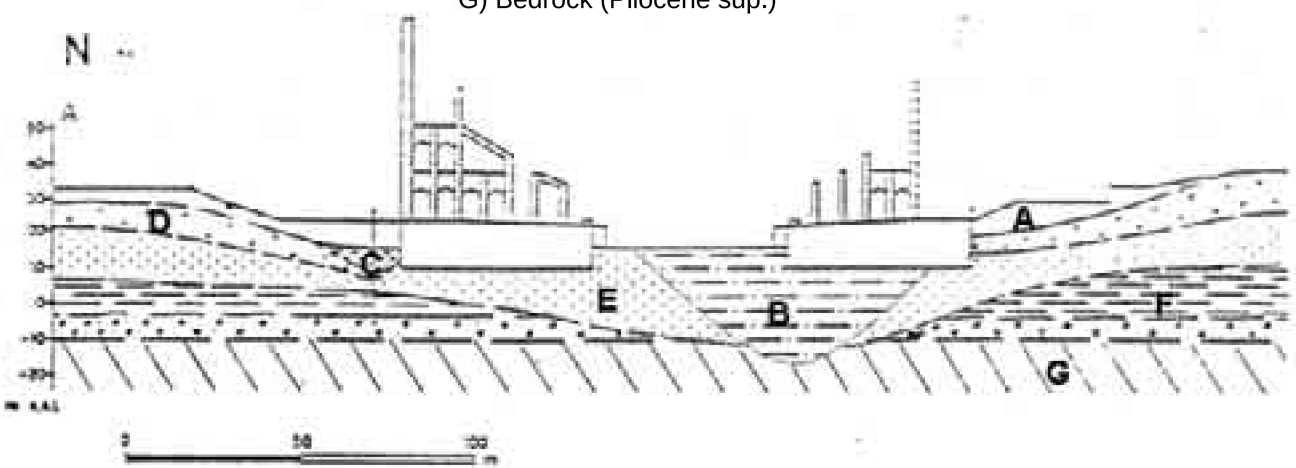
D) Tufi antichi (Pleist. medio)

E) Unità b Paleotevere 2 (Pleist. medio)

F) Unità a Paleotevere 2 (Pleist. medio)

G) Bedrock (Pliocene sup.)





Intensity Scales XX century

Scale MCS (Mercalli – Cancani – Sieberg), 1930

Good for historical events: does not consider the different building types

Scale MM (Modified Mercalli), 1931

Scale MM (Modified Mercalli), 1956

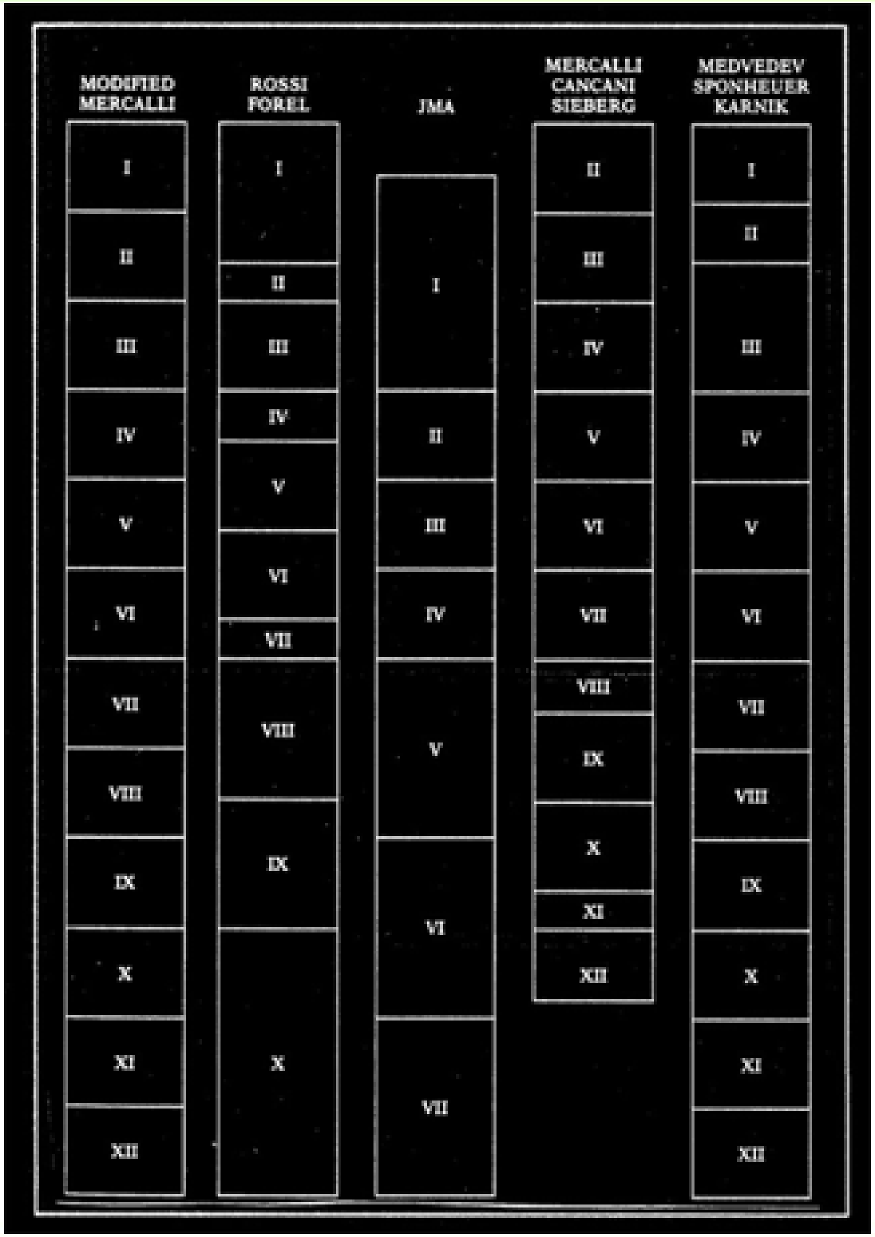
Considers the different building types (4 classes) but not their quality

Scale MSK (Medvev – Sponheuer - Karnik), 1964

Takes into account type of building (3 classes) and level of damage (%)

Scale EMS (European Macroseismic Scale), 1992

Increasing influence of construction type



Comparison among intensity scales
(Reiter, 1990)

How do we locate an earthquake ?

Ground motion

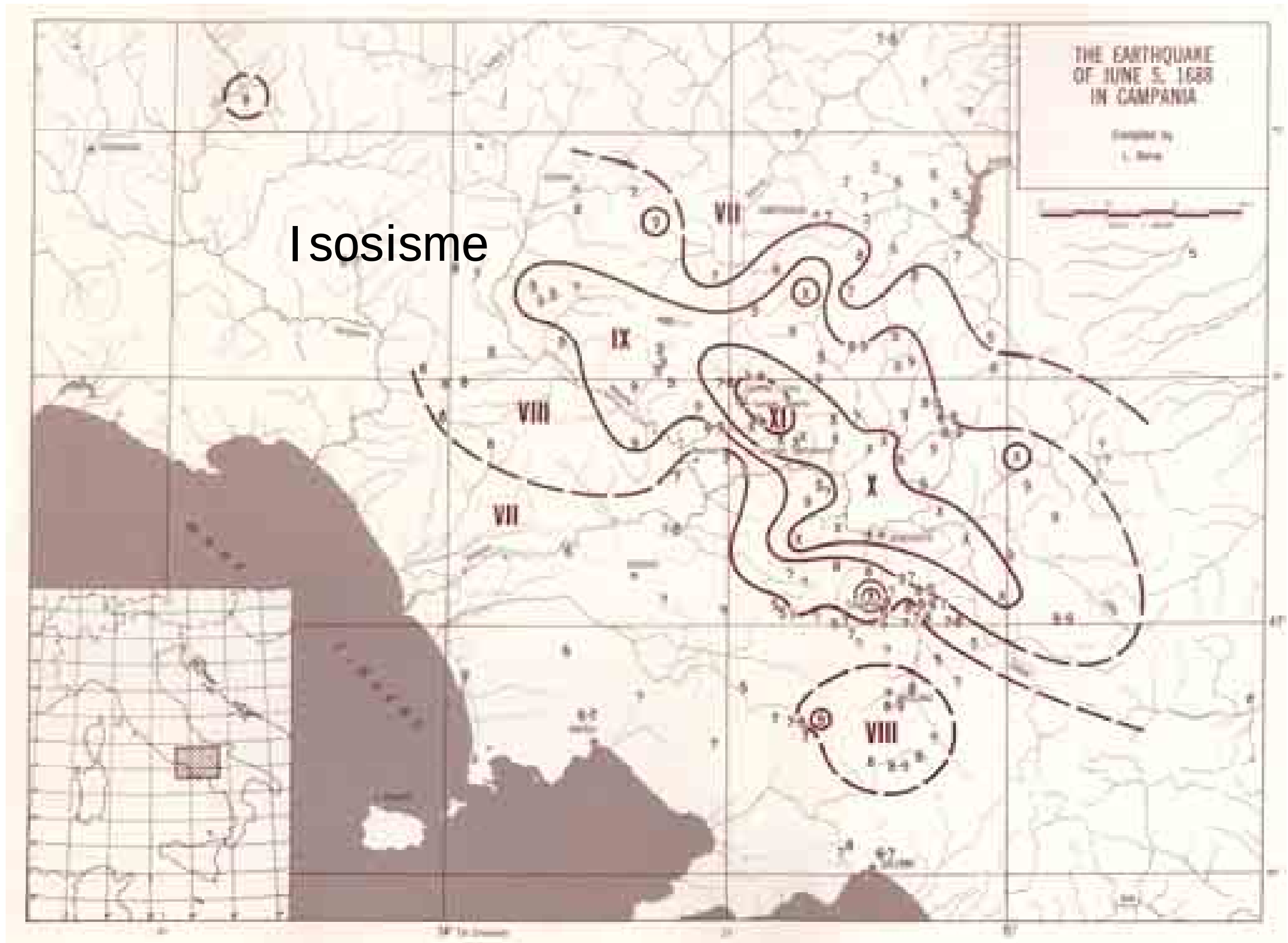
Effects on environment, man, structures

Dromocrones

Intensity

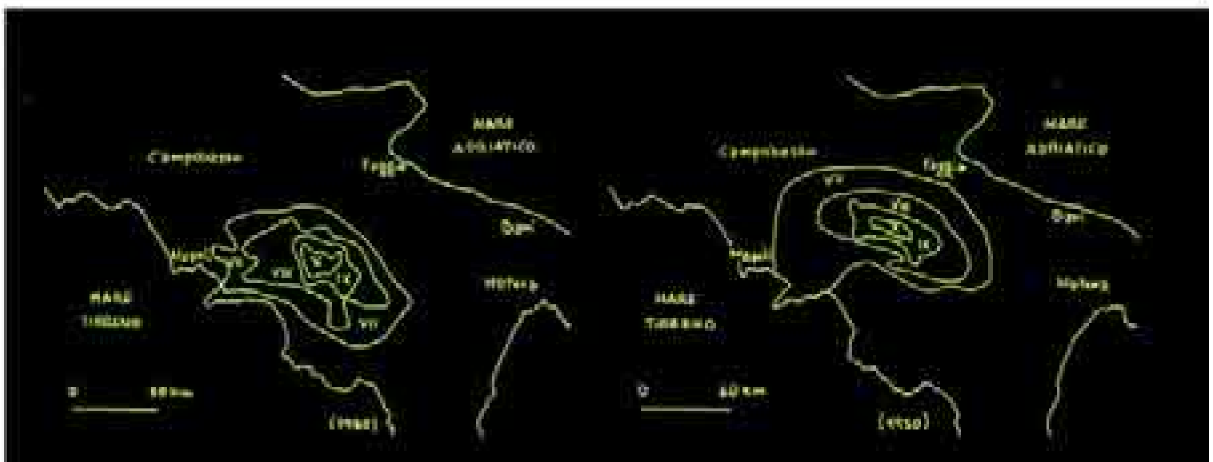
Macroseismic location

Sannio eq.
1688



Isosisme del terremoto di Frascati (10 aprile 1911)

Isosisme del terremoto di Avezzano (13 gennaio 1915)



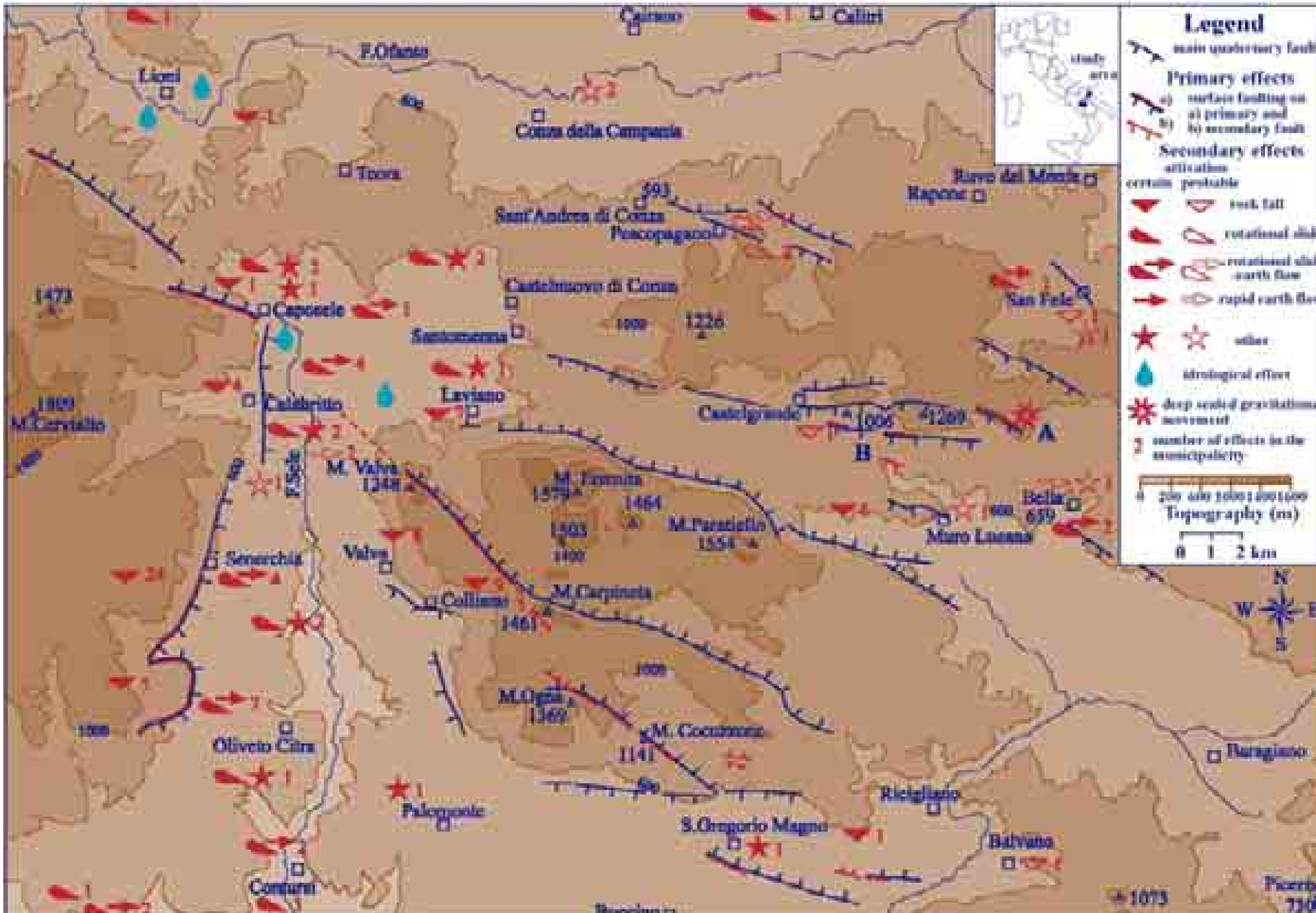
Isosisme dei terremoti dell'Irpinia (1980) e 1930)

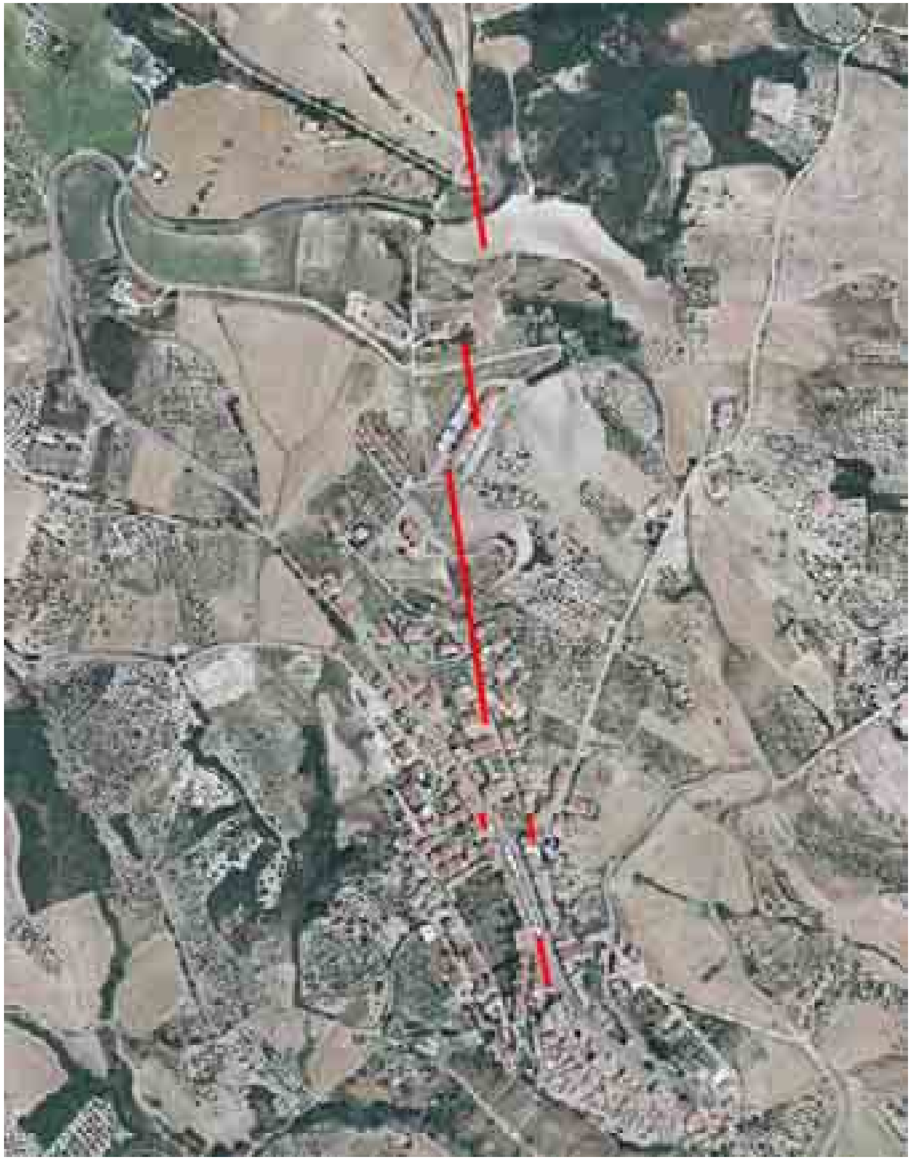
Magnitude and Intensity compared

	Magnitude	Intensity
Time window	narrow (XX sec.)	wide (historic documents for more than 2,000 years)
reliability	Instrumental data	Reading and interpretation of documents variable reliability in different time periods Variable need in different countries to moderate or accentuate the actual damage level influence of man and his structures

Summary table of the effects on the ground described in the intensity scales

Effects	Intensity (MSK)	Intensity (MCS)
-Cracks in saturated soil and/or loose alluvium up to 1 cm,	VI	
- in saturated soil and/or loose alluvium a few cm,	VIII	VIII
- in saturated soil and/or loose alluvium up to 10 cm,	IX	
- in saturated soil and/or loose alluvium a few dm up to one m	X	X
- on road backfills and on natural terrigenous slopes over 10 cm	VII - IX	VIII
- on the dry ground or on asphalted roads	VII – XI	X – XI
-Faults in terrigenous terrains and in rocky terrains	XI - XII	XI
-Liquefaction and or mud volcanoes and/or subsidence	IX – X	X – XI
-Landslides in sand or gravel dykes	VII – X	VII
- in terrigenous slopes	VI – XI	X - XI
-Rockfalls	IX – XII	X – XI
-Clouding in the closed water bodies and formation of waves	VII – IX	VII – VIII
-Water bodies new formation	VIII – XII	XII
-Flooding	X – XII	X
-Water level variation of the groundwater level and the flow rate of springs	V - X	VII - X


Legend
Primary effects
Secondary effects
rock fall
rotational slide
rapid earth flow
other
Topography (m)
0 1 2 km
F.Ofanto
Lioni
Conza della Campania
Teora
Calitri
Sant'Andrea di Conza
Pescopagano
Castelnuovo di Conza
Caposele
Santomenna
Laviano
Calabritto
Castelgrande
Rapone
Ruvo del Monte
San Fele
M.Cervialto
Senerchia
Valva
M. Valva
Colliano
M.Carpineta
M.Paratiello
M.Ogna
M. Cocuzzone
Oliveto Citra
Palomonte
Contursi
Buccino
S.Gregorio Magno
Ricigliano
Balvano
Baragiano
Bella
Muro Lucano
A
B
N
S
W
E



Friuli 1976

Colfiorito 1997

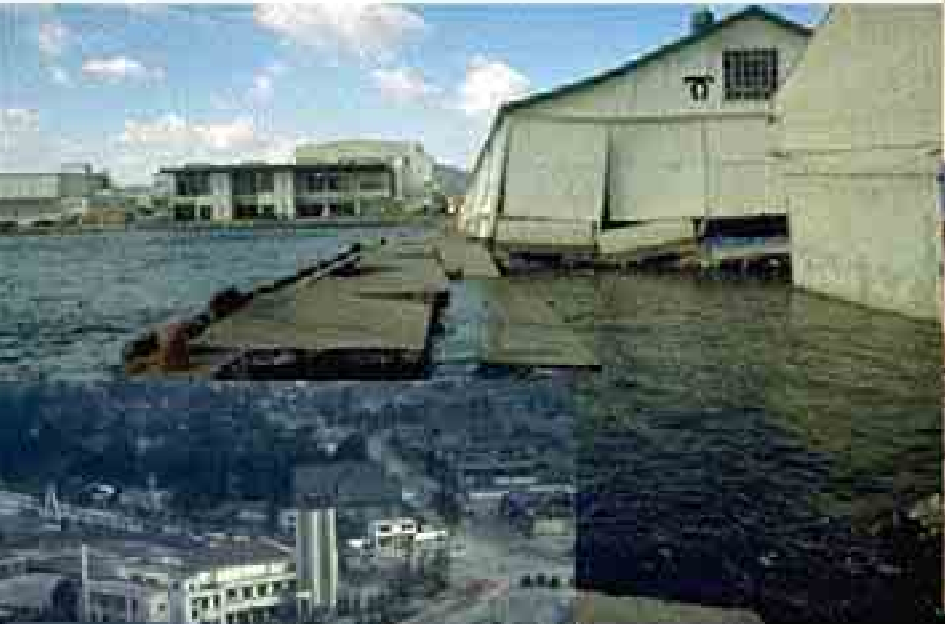
Cerda 2000

Anchorage, Alaska
1964

**Niigata, Giappone
1964**


IIEES

Montenegro, 1979



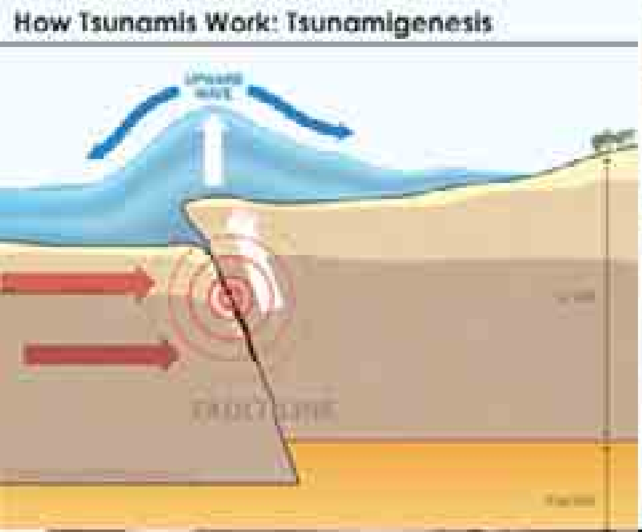
Kobe, 1995

Niigata, 1964

San Fernando CA, 1971

16.06.1964, Ms 7.5 Niigata (Japan)

TSUNAMI



CORRAL BAJO, CHILE, AFTER TSUNAMI OF MAY 22, 1960


3
Ubicación de zonas dañados
ZONA DE DAÑOS 1985
ZONA DE DAÑOS MAYORES 1985
ZONA DE DAÑOS 1957
ZONA DE DAÑOS 1979

PROJECT:

VULNERABILITY OF WATER SUPPLY NETWORK BY CAPABLE FAULTS IN THE ETNEAN REGION (EASTERN SICILY)

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Fabio BADALAMENTI (**), Antonino BRANCATO (**)

Project lead partner:

*Italian Agency for Environment Protection and for Technical Services (APAT)

Project partner:

**Regional Agency for Environment Protection of Sicily (ARPAS)

Main project

The experience acquired in the field during the earthquake of 2002 in the Etna region in Eastern Sicily has suggested the need for an effective tool for the reduction of environmental risk related to surface faulting, either during emergencies and in the planning and assessment stages. So, a georeferenced database has been created, where capable faults and water supply are overlapped and intersections (zones of expected peak damage and failure) easily evidenced.

Programme activities

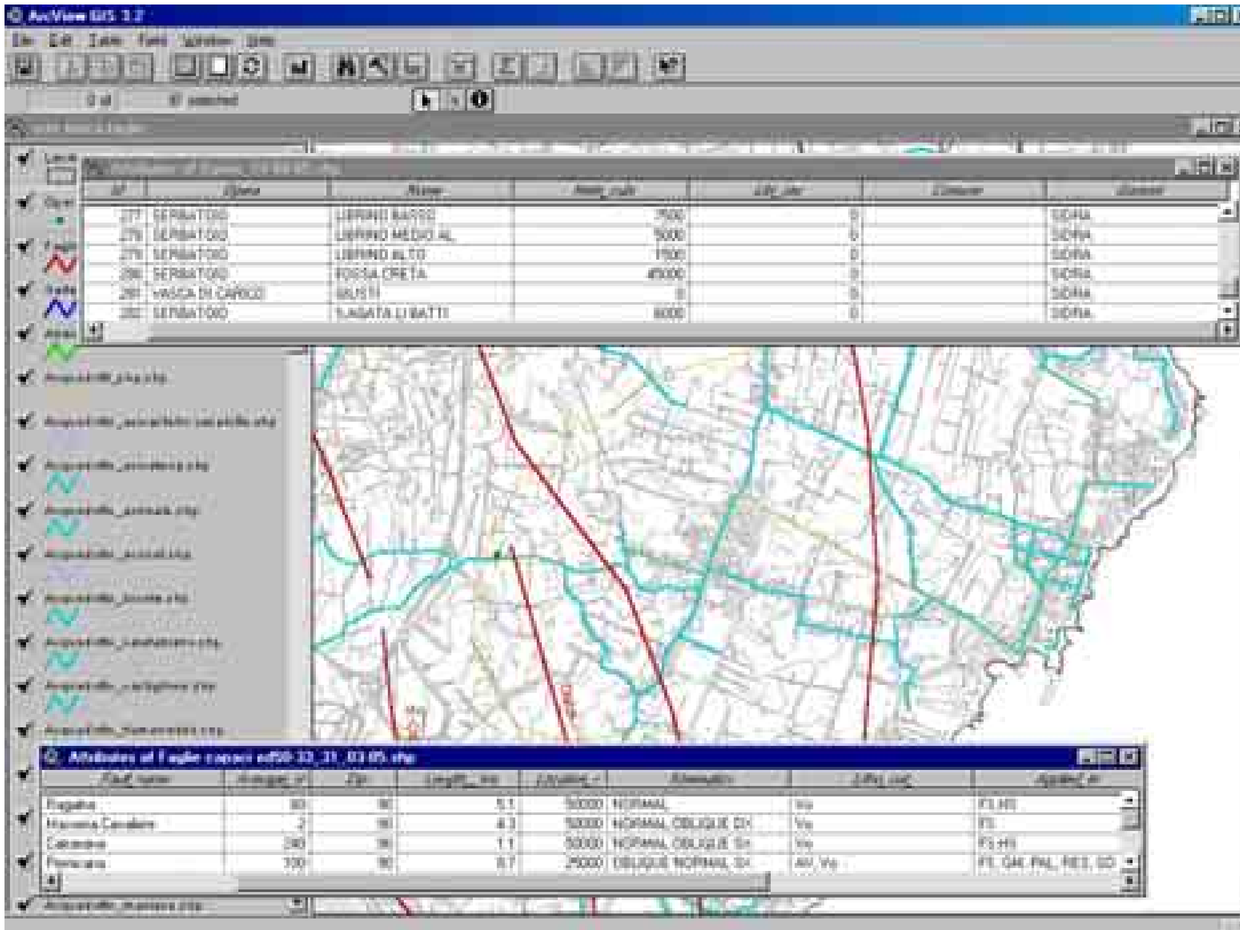
1) Collection of data regarding capable faults (from published reports, scientific papers, field analyses and paleoseismological analyses – ITHACA DB)

2) Collection of data regarding water supply networks (outlet, wells, springs, water pipes, etc.., from water

Programme activities

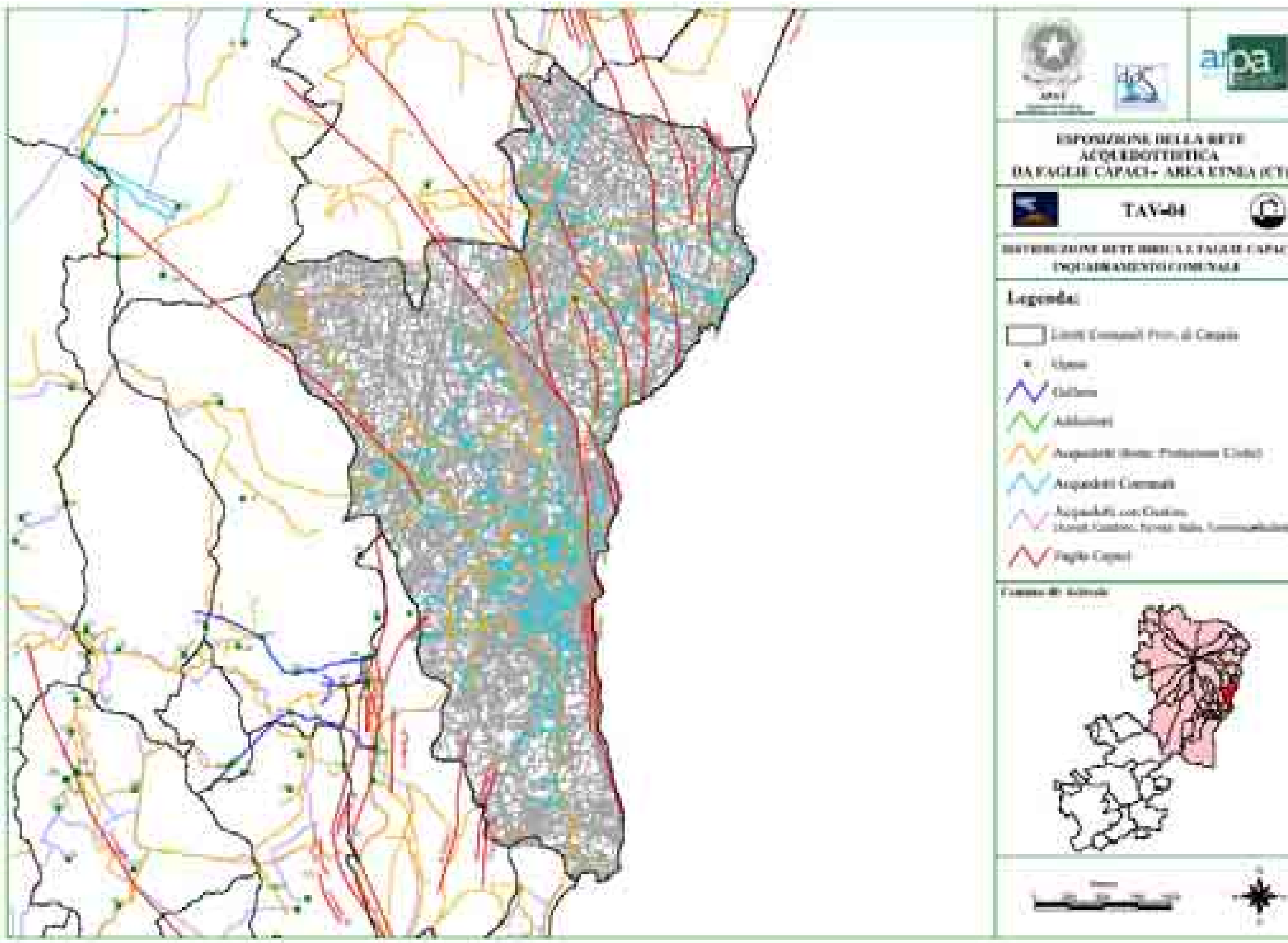
3) Data verification by field surveys.

4) Compilation of geodatabase (capable faults and water supply network).



Main results

1) Identification of intersections between faults and water pipes (zones of expected peak damage and failure – highest vulnerability).



Main results

2) Availability of a fundamental tool, when facing the problem of land planning in so vulnerable zones and during the emergency, when it is crucial for the environmental agency to quickly verify the integrity of the water network and find the ruptured and leaking points, where contamination is to be expected from other networks, e.g. the sewage system.

3) Successful participation to an international civil protection exercise, simulating a strong earthquake in eastern Sicily (EUROSOT 2005).

Future activities planned

- Now the project covers the Etna volcanic region, the most vulnerable in Sicily, but it is under evaluation its possible extension to the whole Sicily.
- It is planned for the next future, depending on available resources, to overlap the capable faults data with other environmentally-sensible networks (gas, oil pipes, sewage, etc..) or important human structures (roads, railways, strategic buildings, environmentally-sensible industrial plants, etc..).
- The same strategy can be applied to landslides and flood-prone areas

In the XVIII century the great philosopher Immanuel Kant, in his dissertation inspired by the Lisbon eq. of 1755, stated:

“Earthquakes have revealed to us that the Earth surface is made of vaults and caverns and that under our feet hidden galleries and an infinite number of labyrinths extend everywhere. The description of the earthquake will clarify this point leaving <u>absolutely no doubts</u> about it.”

Sic est…