Seismic risk in the Alpine structure

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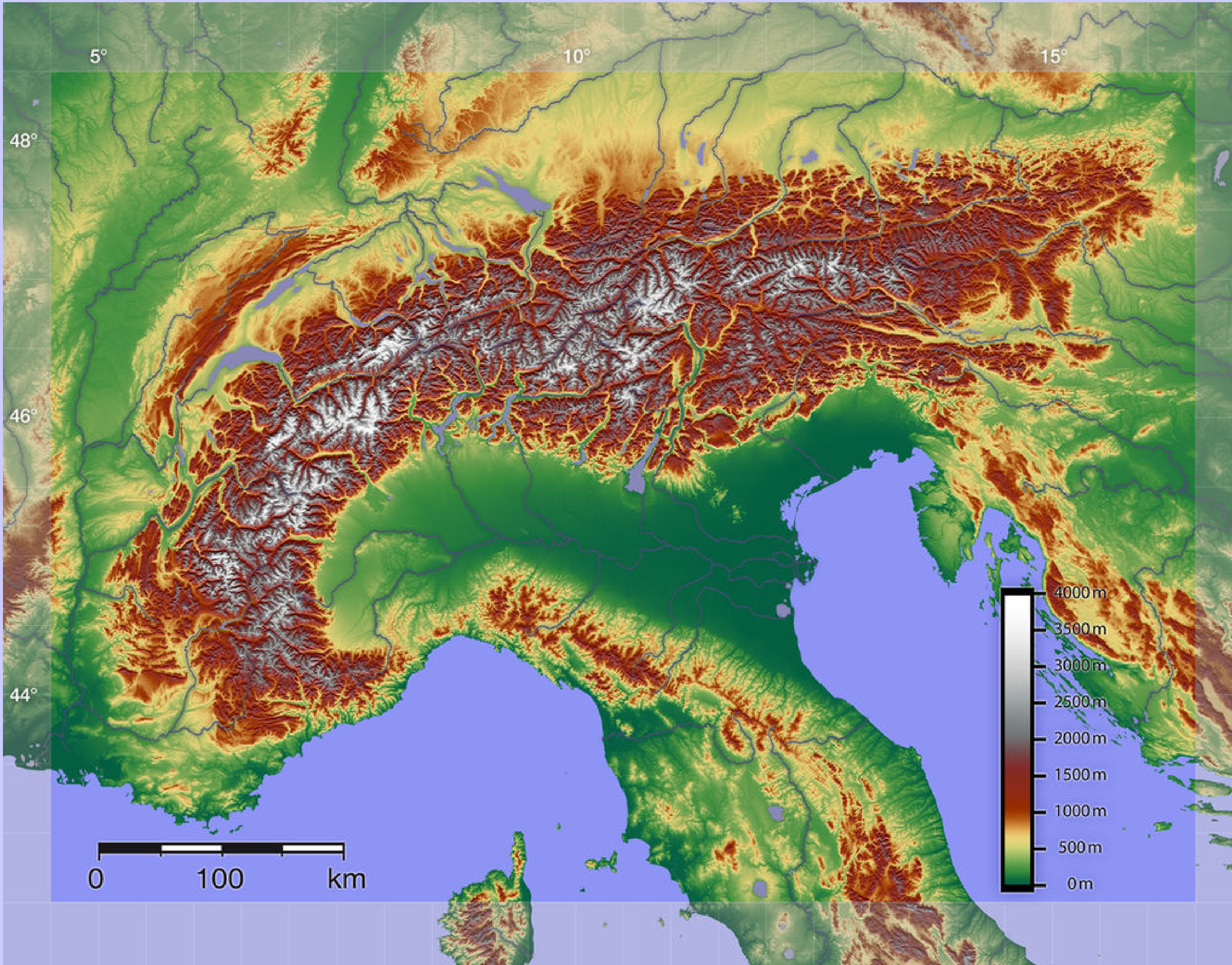

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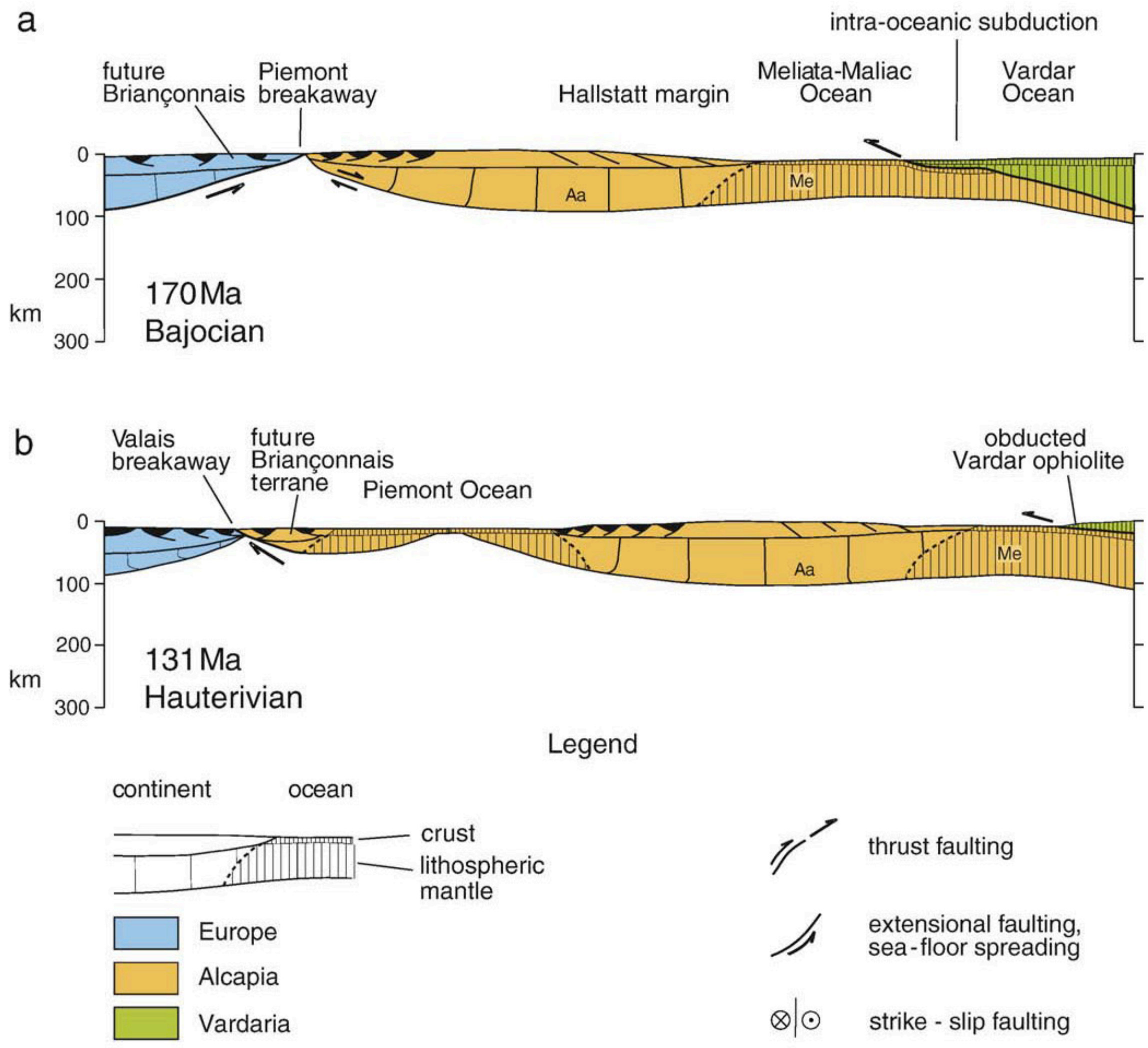

Fig. 9. Cross sections through Alpine Tethys and part of Neotethys: (a) 170 Ma, onset of spreading in Piemont part of Alpine Tethys; intra-oceanic obduction of Var lithosphere; (b) 131 Ma, end of spreading in Piemont part of Alpine Tethys and onset of Eo-alpine orogenesis; Location of cross sections shown in Fig. 8. Horizontal vertical scale. Aa = Austroalpine (Alcapia) continental lithosphere, Me = Meliata–Maliac oceanic lithosphere.

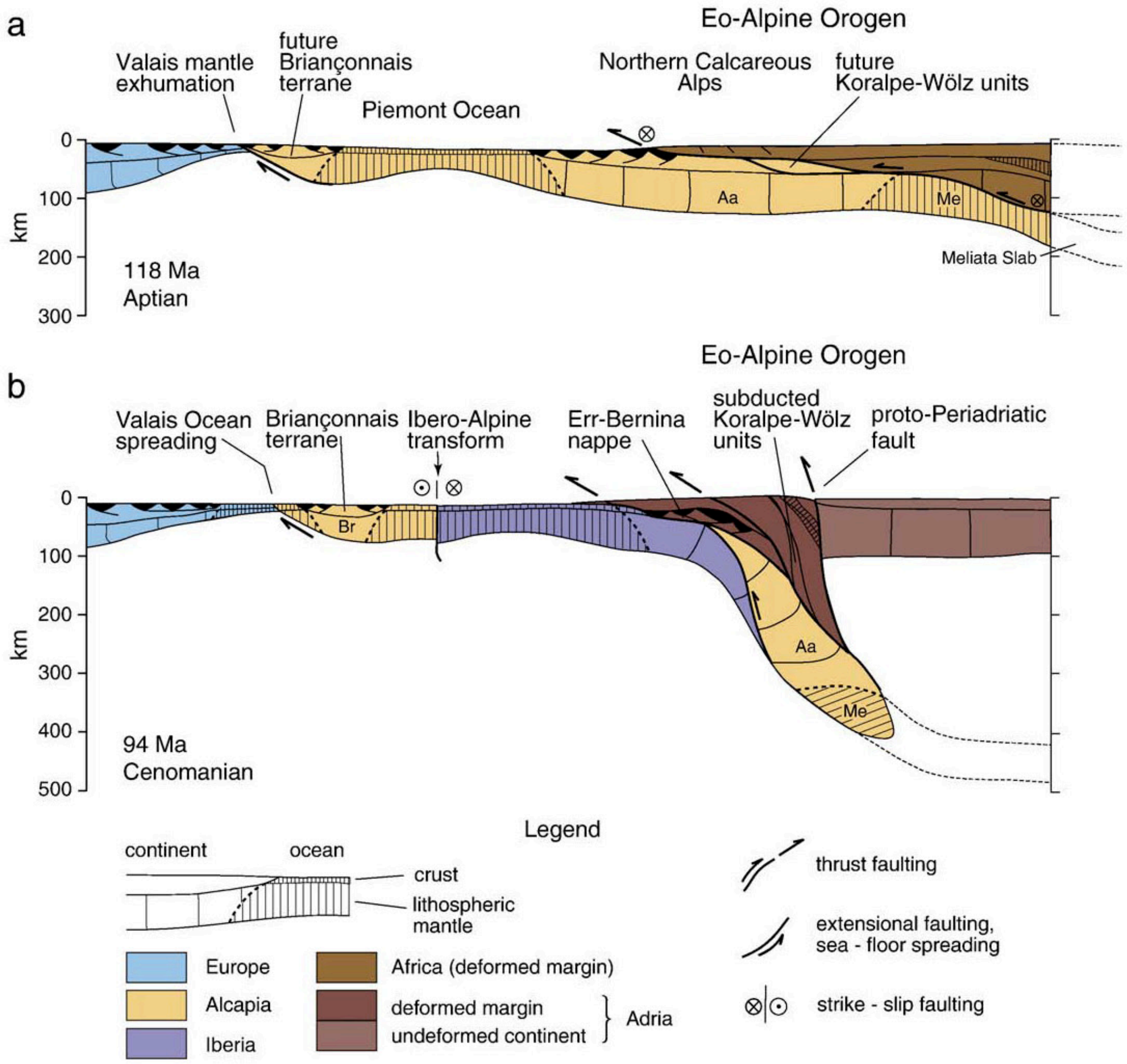

Fig. 11. Cross sections through Alpine Tethys and adjacent continental margins in Late Cretaceous time: (a) 118 Ma, spreading of Valais Ocean linked to Eo-alpine orogenesis, with dashed lines showing probable eastward continuation of the Adriatic lithosphere and the subducted slab of Alcapia (including Meliata oceanic lithosphere); (b) 94 Ma, onset of active margin tectonics only at western end of Eastern Alps due to convergence of Iberia and Alcapia; intracontinental subduction in Eastern Alps. The dashed lines indicate the lateral continuation of the slab of Neotethyan (Me = Meliata–Maliac) oceanic lithosphere behind, i.e., ENE of the plane of the cross section. Location of cross sections shown in Fig. 10. Horizontal scale equals vertical scale. Aa = Austroalpine (Alcapia) continental lithosphere, Br = Briançonnais continental fragment, Me = Meliata–Maliac oceanic lithosphere.

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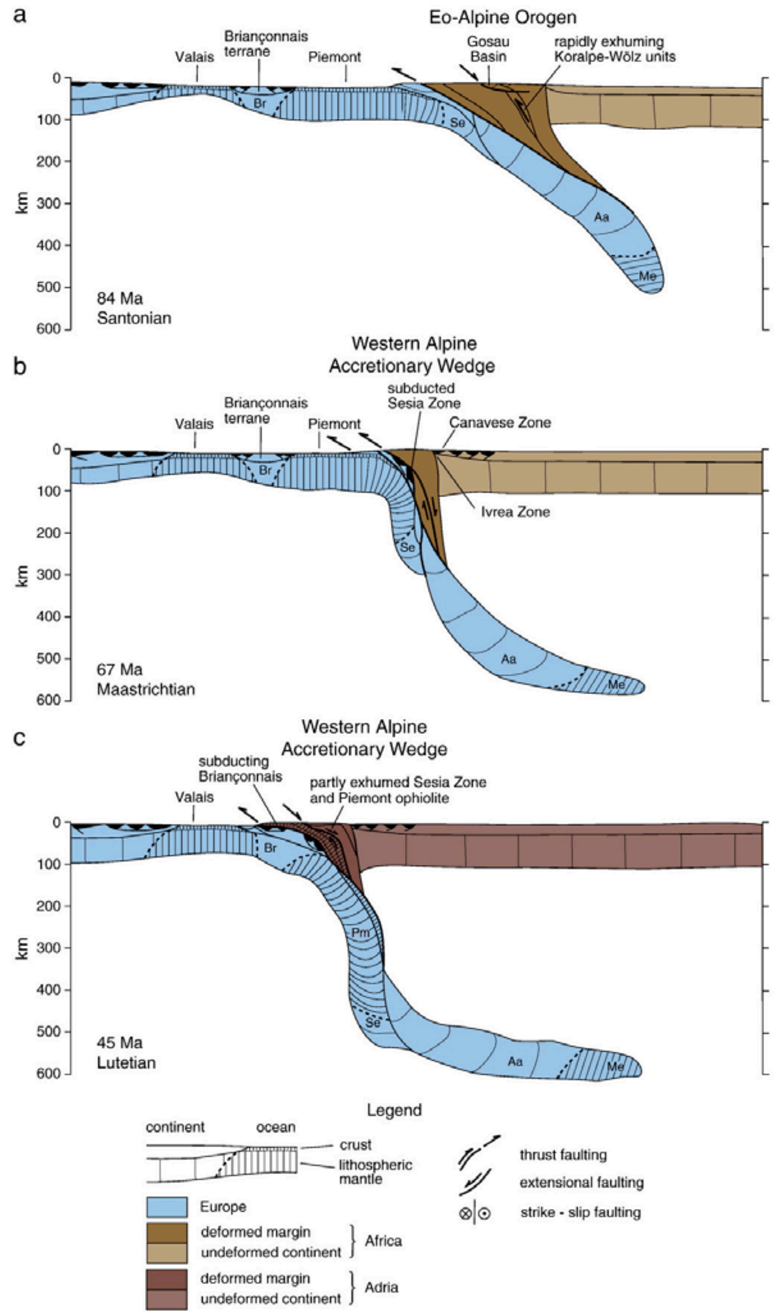
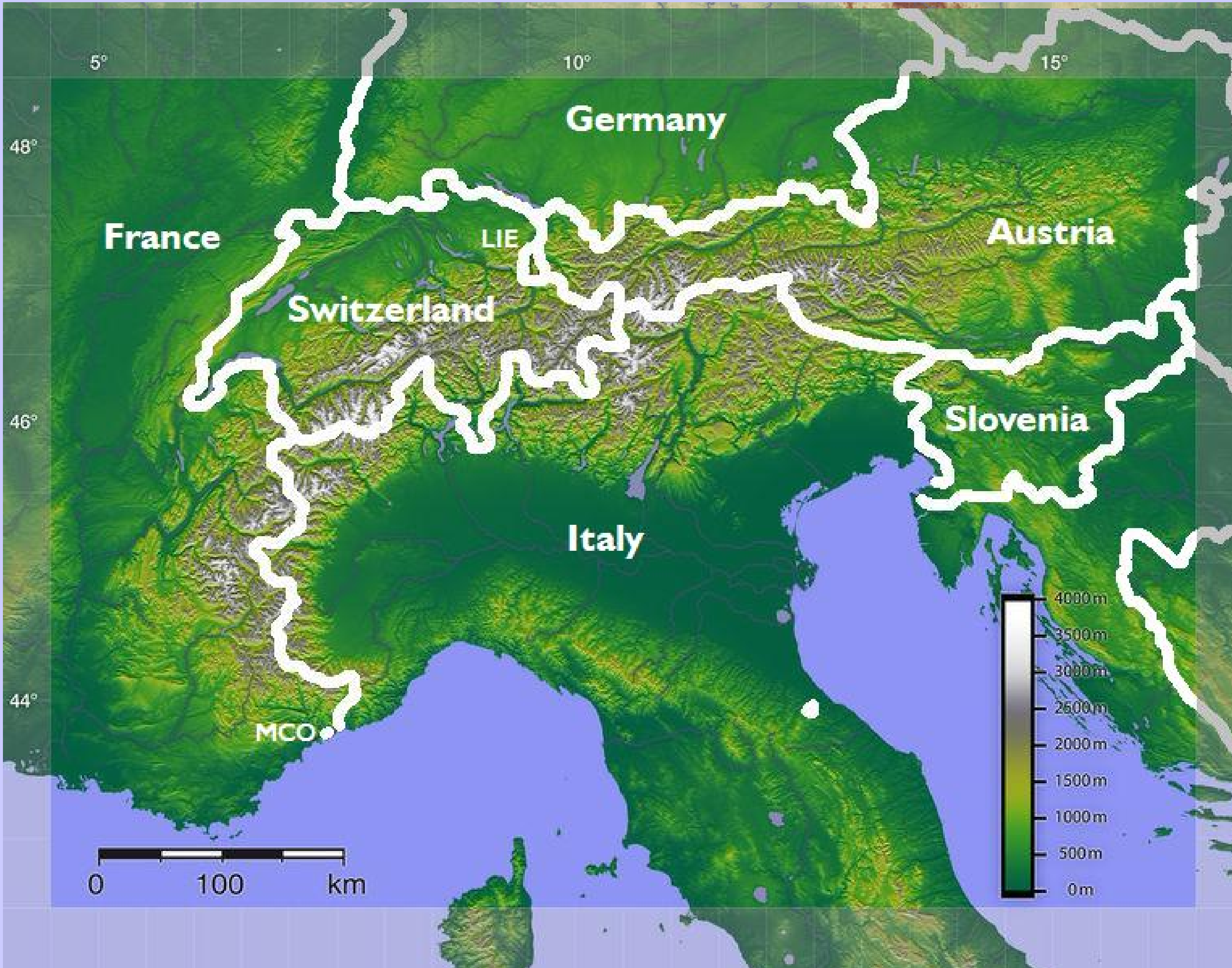


Fig. 13. Cross sections through Alpine Tethys during Late Cretaceous time: (a) 84 Ma, onset of subduction related to NW motion of Africa, rapid exhumation of Koralpe-Wölz unit; (b) 67 Ma, subduction of western tip of the Adriatic continental promontory (Se = lithosphere of the Sesia Zone) and formation of the Western Alpine accretionary wedge; (c) 45 Ma, Early Cenozoic accretion and imbrication of Piemont oceanic crustal slices, subduction of the Briançonnais continental fragment (Br). Location of cross sections shown in Fig. 12. Horizontal scale equals vertical scale. Aa = Austroalpine (Alcapia) continental lithosphere, Me = Meliata–Maliac oceanic lithosphere, Pm = Piemont oceanic lithosphere.

Tectonic evolution of the western Mediterranean since the Oligocene

Rosenbaum, G., Lister, G. S. Duboz, C.

Journal of the Virtual Explorer, 8, 107 - 126., 2002



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RISK = HAZARD x VULNERABILITY

RISK = HAZARD x VULNERABILITY x EXPOSURE

LOSS = HAZARD x VULNERABILITY x EXPOSURE

HAZARD: estimates the expected ground motion at the earth's surface. The computation of seismic hazard is the result of a complex process that takes into account the regional geology, the local and regional instrumental seismicity (in average the last 50 years), the historical seismicity (in average the last 1000 years), the location of seismic faults.

The results are often displayed in maps in which areas of similar "seismic" potential have similar colours.

The mapped hazard refers to an estimate of the probability of exceeding a certain amount of ground shaking, or ground motion, in a certain amount of years (usually 50).

The maps can be drawn using peak ground acceleration, peak velocity, intensity or more sophisticated units.

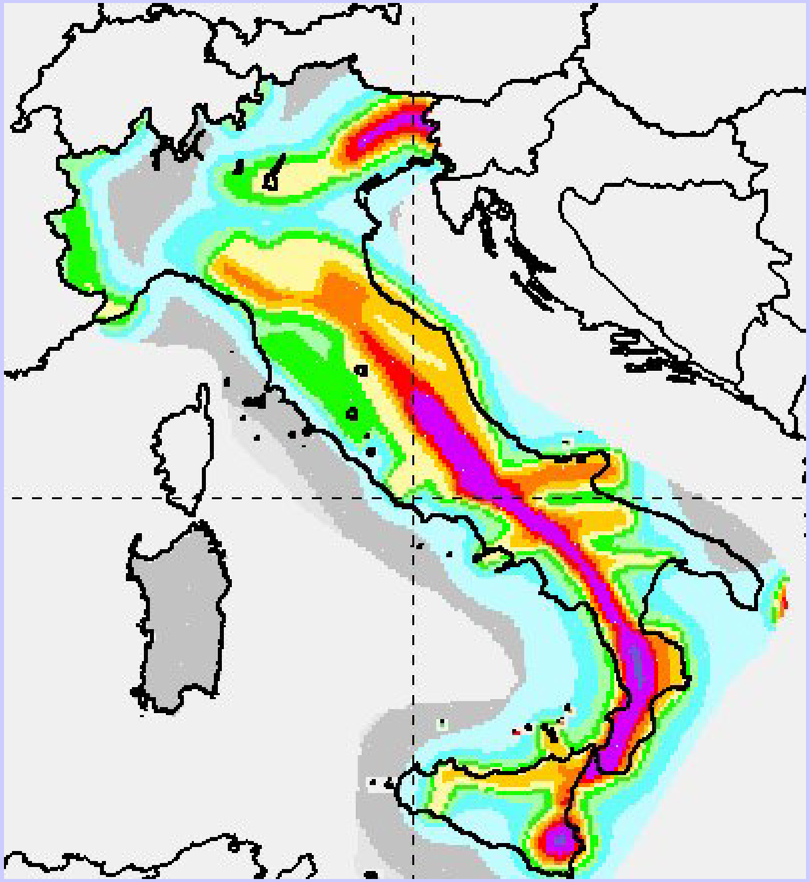
The hazard depends on the magnitudes and locations of likely earthquakes, how often they occur, and the properties of the rocks and sediments that earthquake waves travel through.

In particular the last part of the path of the seismic wave is characterized by very local properties.

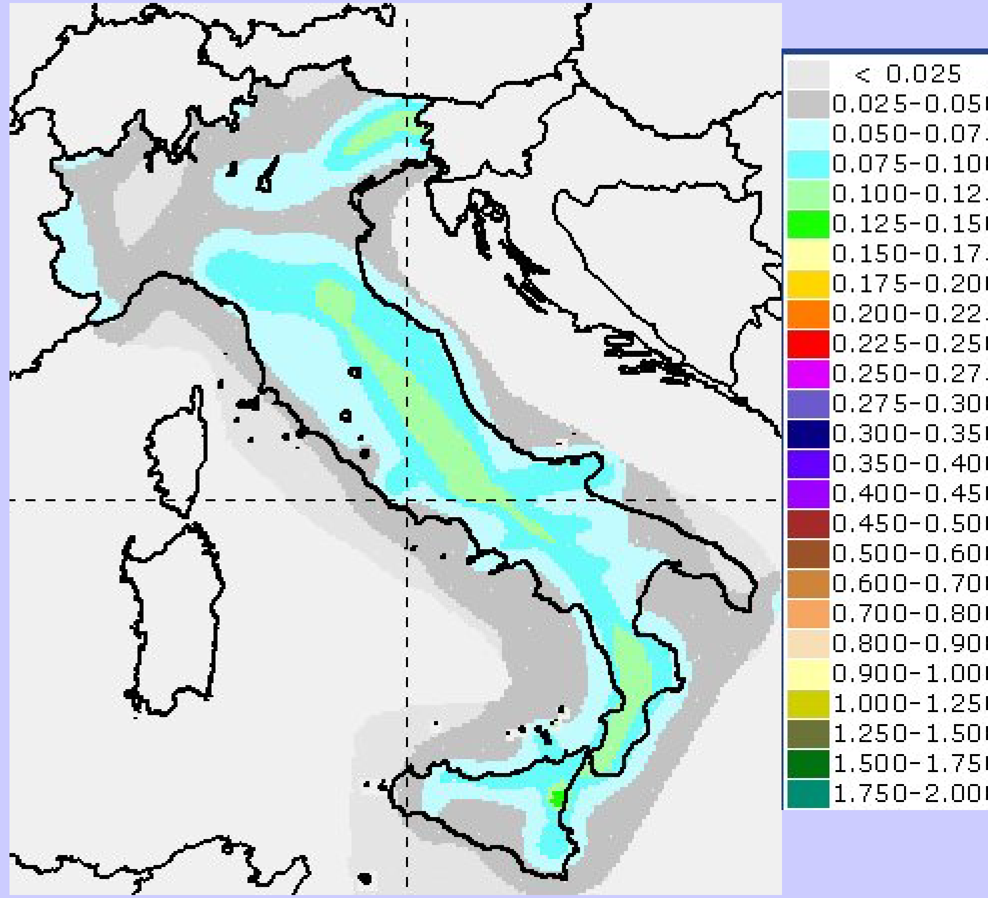
For this reason maps are often computed for rock and a specific coefficient is applied to take into account the local variability.

This coefficient is very strictly linked to what we call site-effects.

Hazard maps are apparently very easy to read (color spots) but are very difficult to interprete.

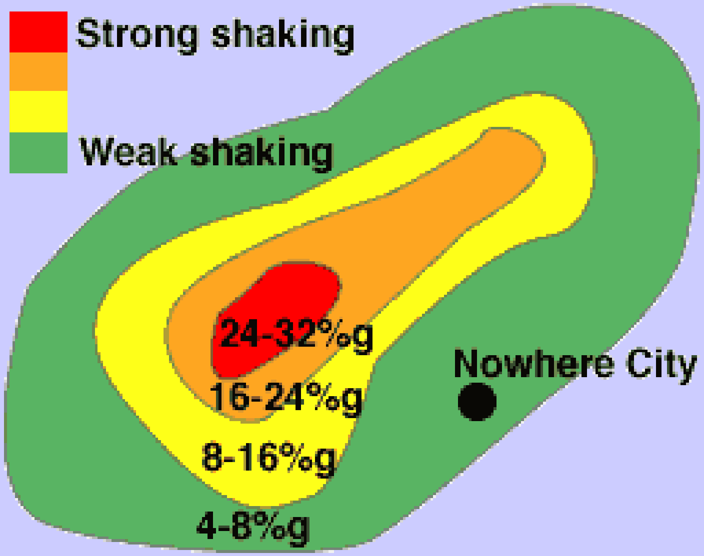


10% 50 years



50% 50 years

The earthquake peak ground acceleration (PGA) that has a % chance of being exceeded in x years



(www.usgs.gov)

Suppose the map on the left is the map given:
A 50-year time interval
A 5% chance of exceedence
A PGA map

We would read the shaking hazards for Nowhere City as:
The earthquake peak ground acceleration (PGA) that has a 5% chance of being exceeded in 50 years has a value between 4 and 8% g.

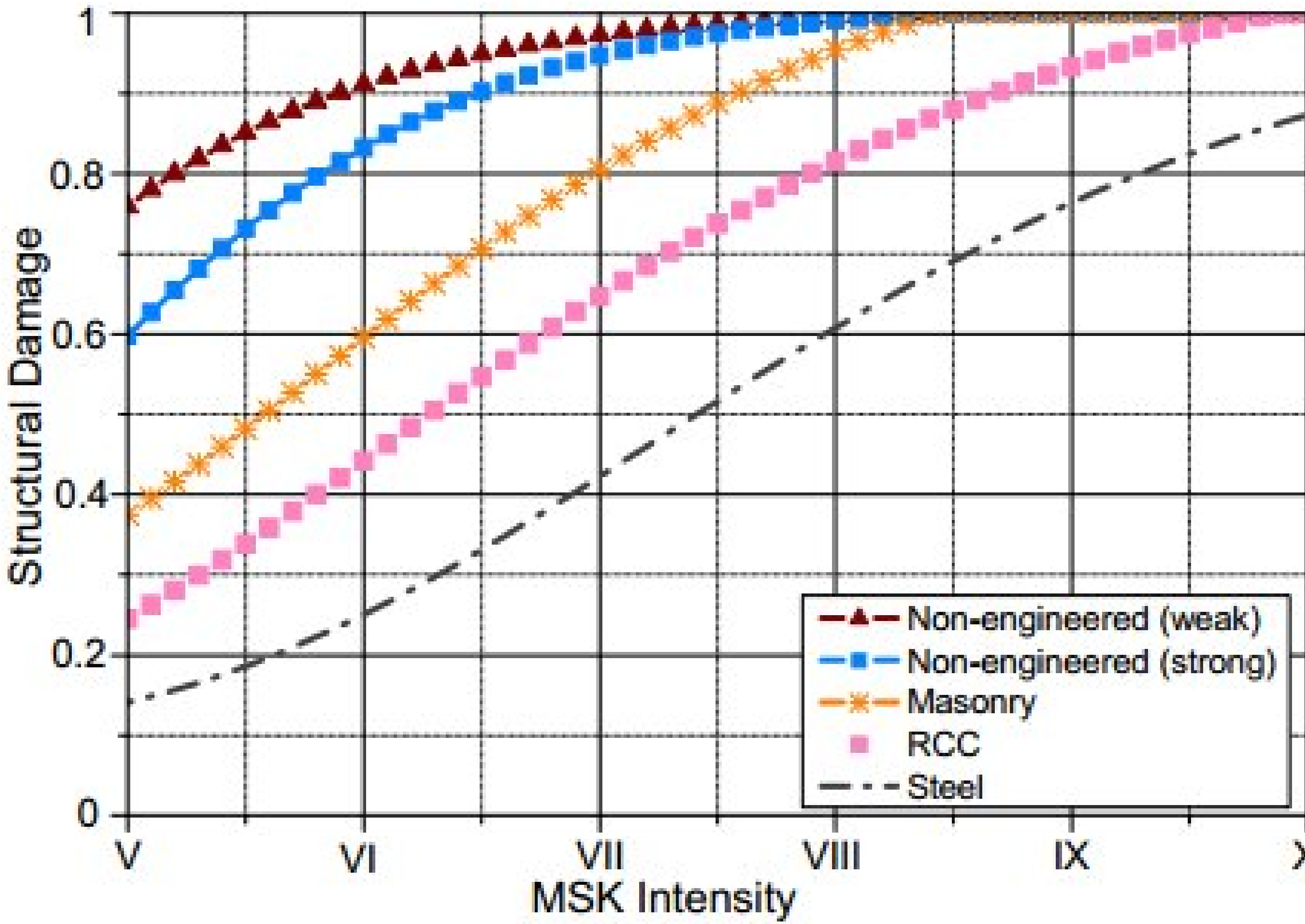
Vulnerability

In general, it defines the (level of) expected damage for a buidling or a class of buildings as a function of the ground motion. It ranges from 0 to 1, 10 or 100 depending on the kind of estimate used.

Examples of vulnerability computation:

Table 3 Seismic vulnerability assessments

Structural seismic capacity index I_s and lateral force capacity index q	Vulnerability assessment
$I_s < 0.3$ or $q < 0.5$	Likely to collapse
others	Possible to collapse
$I_s \geq 0.6$ and $q \geq 1.0$	Unlikely to collapse


Structural Damage
1
0.8
0.6
0.4
0.2
0
V
VI
VII
VIII
IX
X
MSK Intensity
Non-engineered (weak)
Non-engineered (strong)
Masonry
RCC
Steel

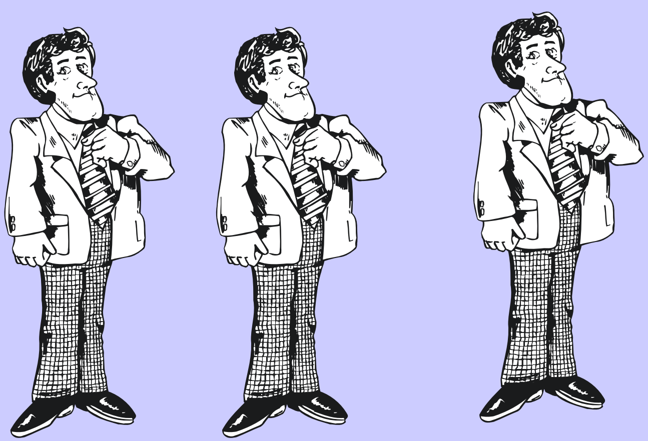
Exposure

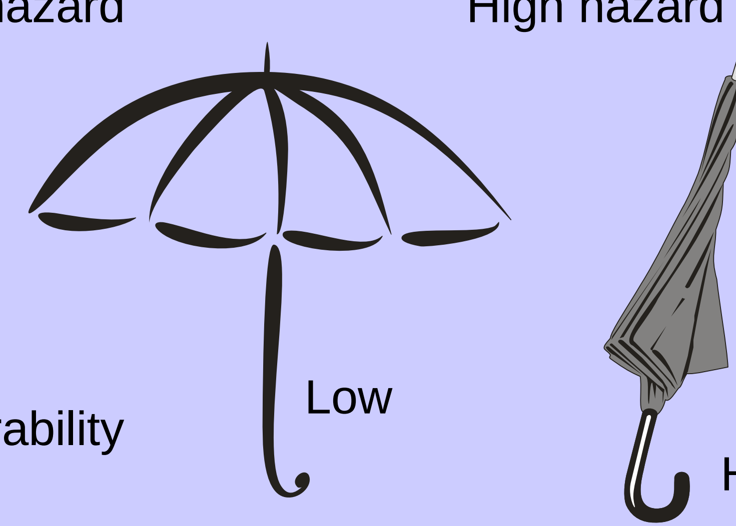
It basically consists in the amount of "items exposed" to ground shaking. It includes number of people and (as a consequence) infrastructures and buildings "exposed" to seismic shaking.
Earthquake casualties are limited by the number of people present in stricken areas, and losses are constrained by the quantity and value of the buildings, infrastructure, and other property in those areas. Seismic risk increases as earthquake-prone regions become more densely populated and urbanized.

Low hazard

Medium hazard

High hazard





Vulnerability

Low

High

Exposure

Vulnerability

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Worst scenario (higher risk)

High hazard

High vulnerability

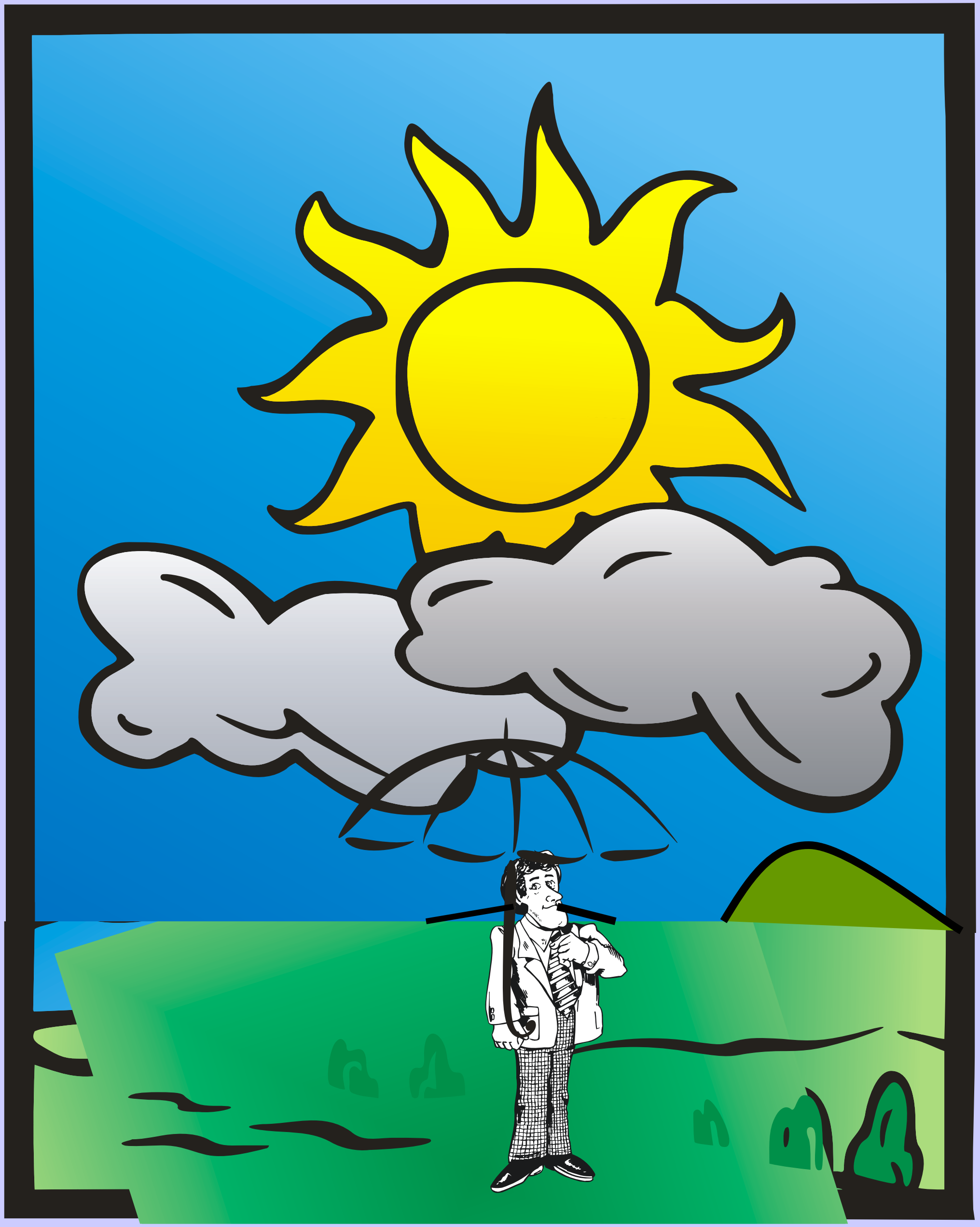
High exposure

Best scenario (lower risk)

Low hazard

Low vulnerability

Low exposure

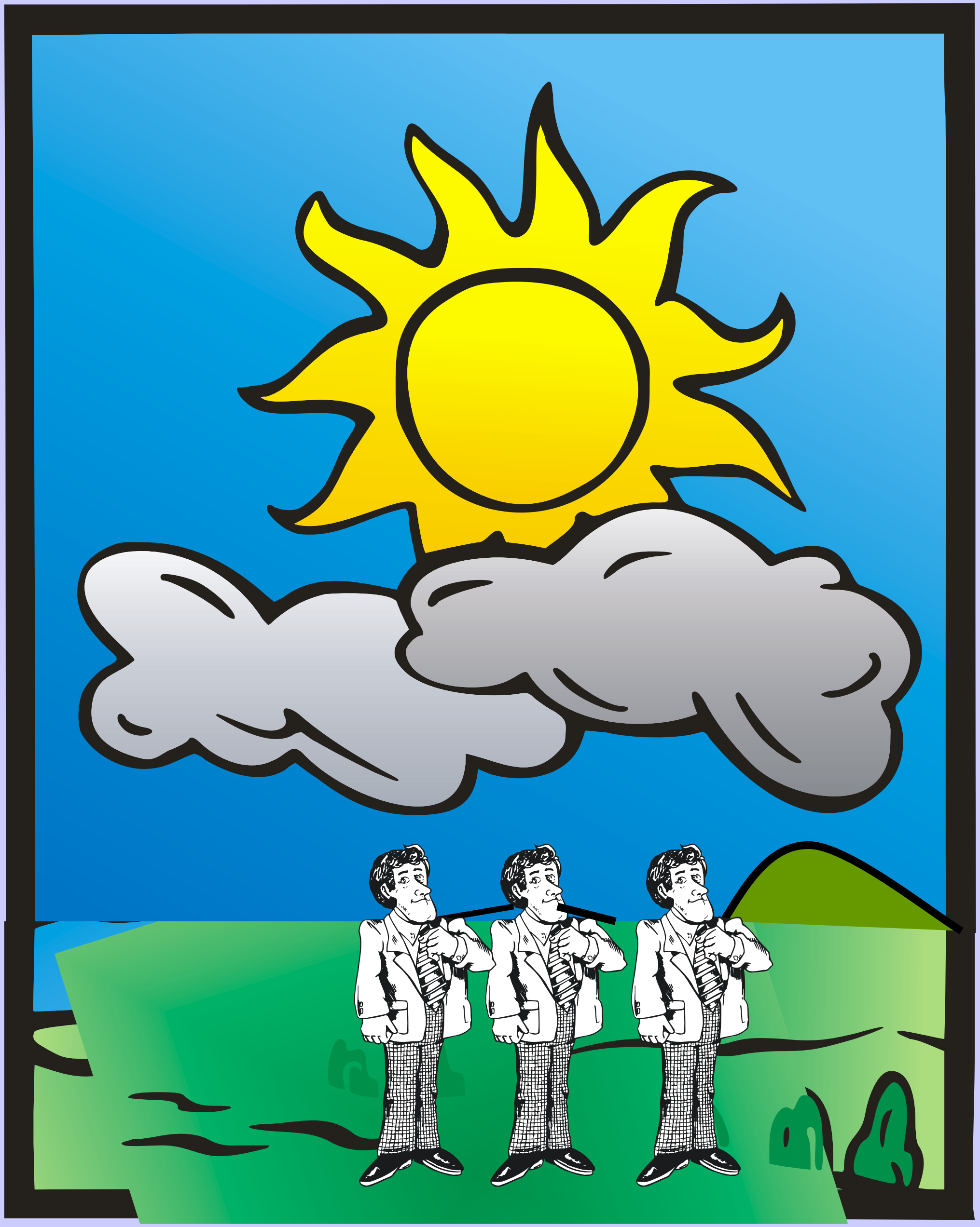


Bad scenario (medium risk)

Low hazard

High vulnerability

High exposure



HAZARD

RISK = HAZARD x VULNERABILITY x EXPOSURE

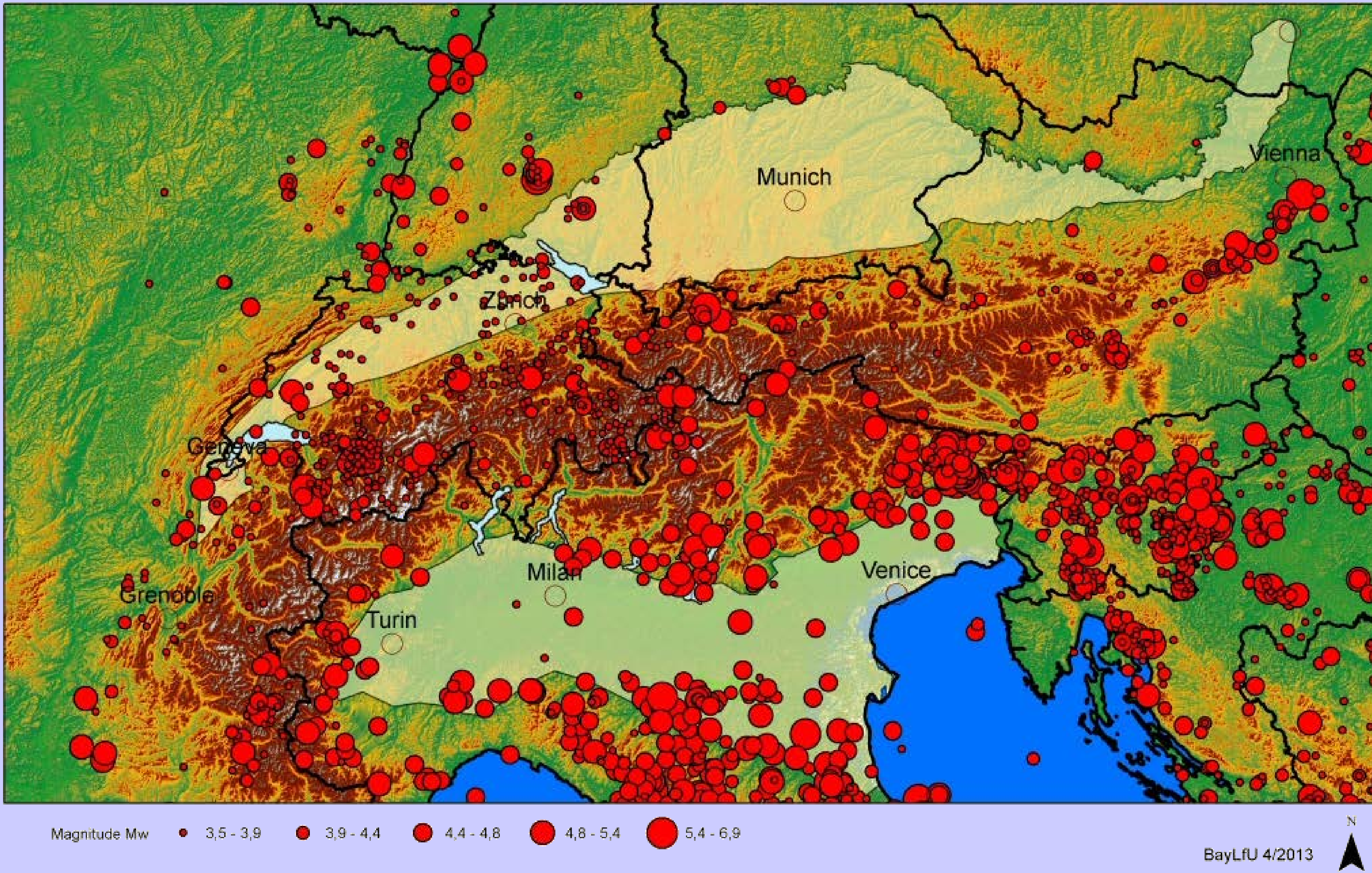
"Ingredients" for hazard

- Historical seismicity (1000-1900)
- Instrumental seismicity (1900-today)
- Geology
- Characteristics of the faults (extension, kinematics)
- Attenuation laws
- Map and estimate of the site local effects

↓

Area source model

Area sources are polygons that comprise a region thought to have homogeneous seismic activity within the area of the polygon.



Seismicity Mw > 3.5 1000-2006 (Grünthal & Wahlström (2012):

SHARE

EFEHR

Hazard Map

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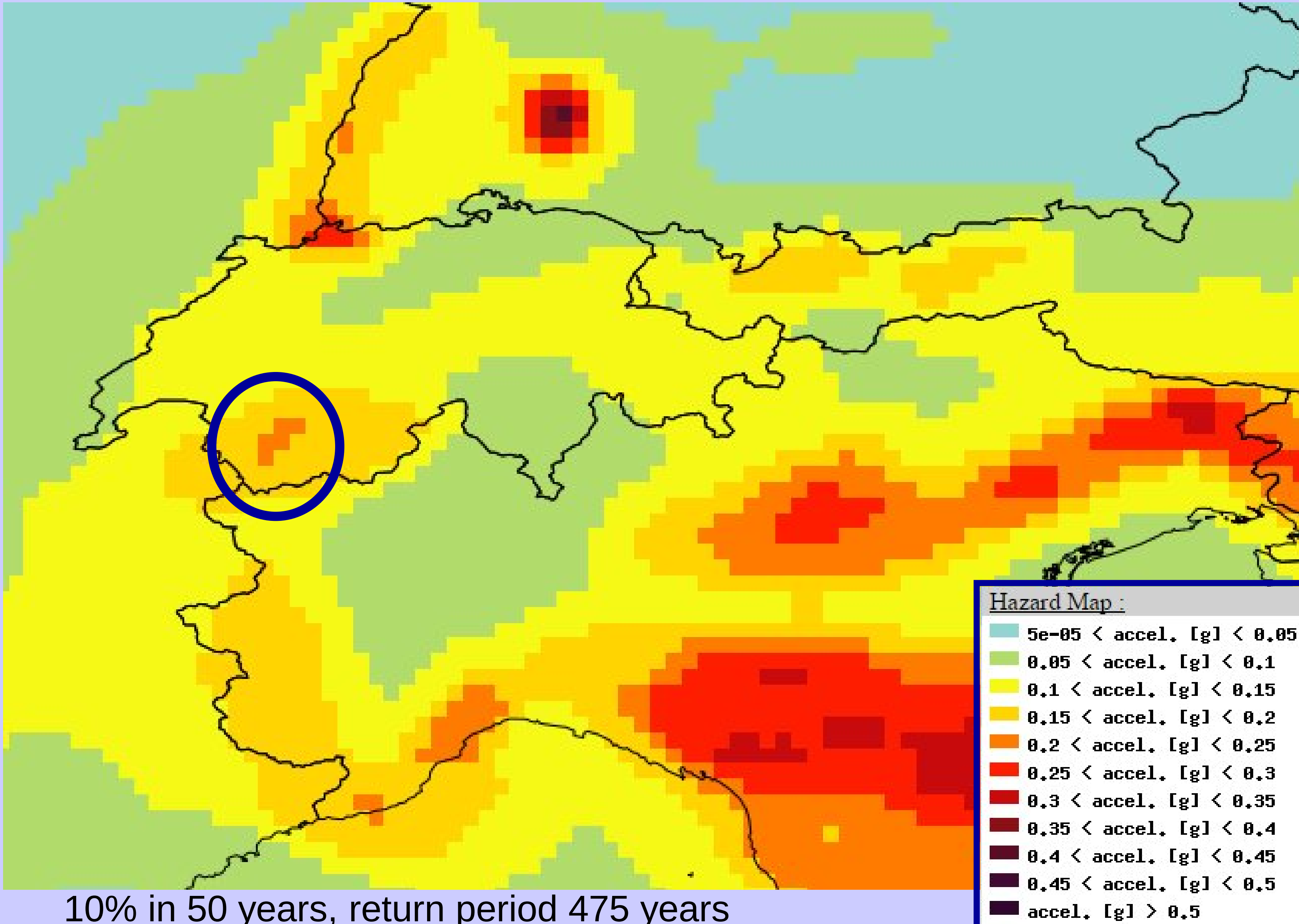
EFEHR
European Facility For Earthquake Hazard And Risk

Introducing EFEHR | Seismic Hazard | Exposure & Vulnerability | Seismic Risk | Web Service Documentation



10% in 50 years, return period 475 years
PGA map, g

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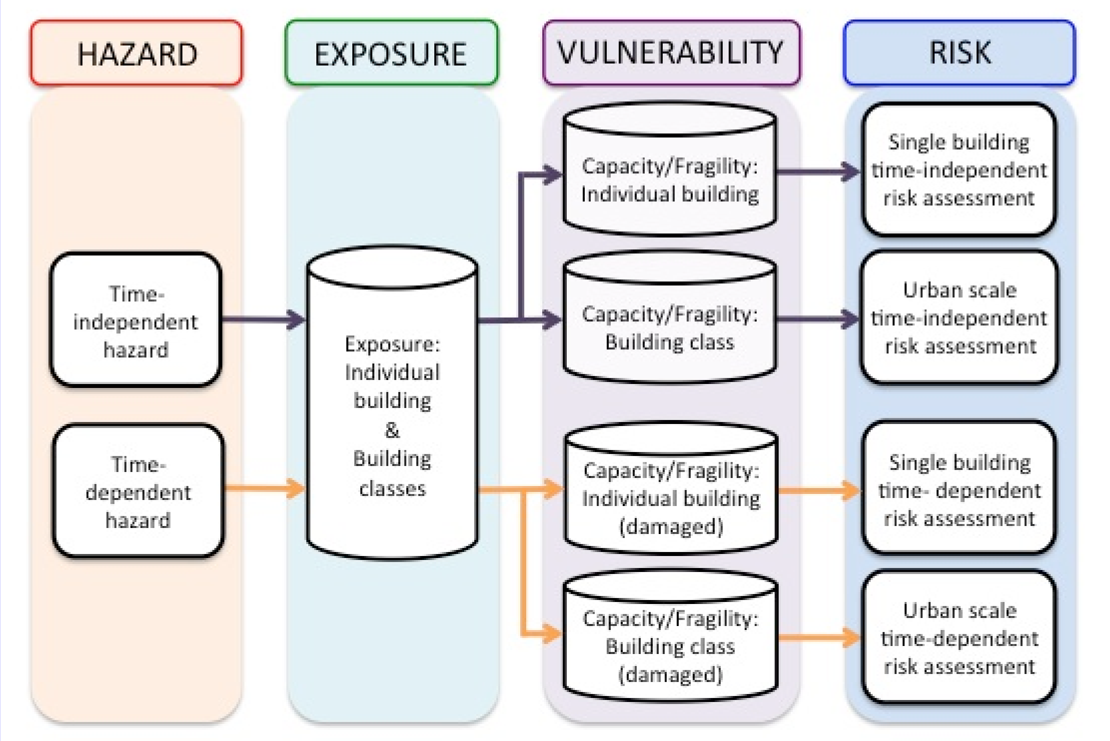
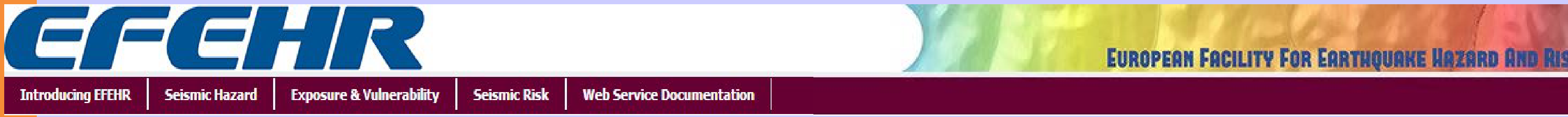
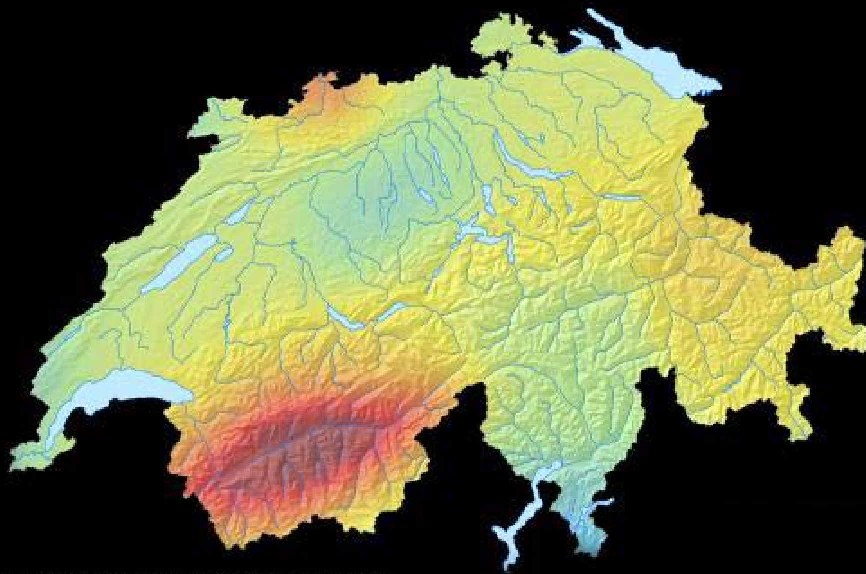
http://www.efehr.org:8080/jetspeed/portal/default-page.psml



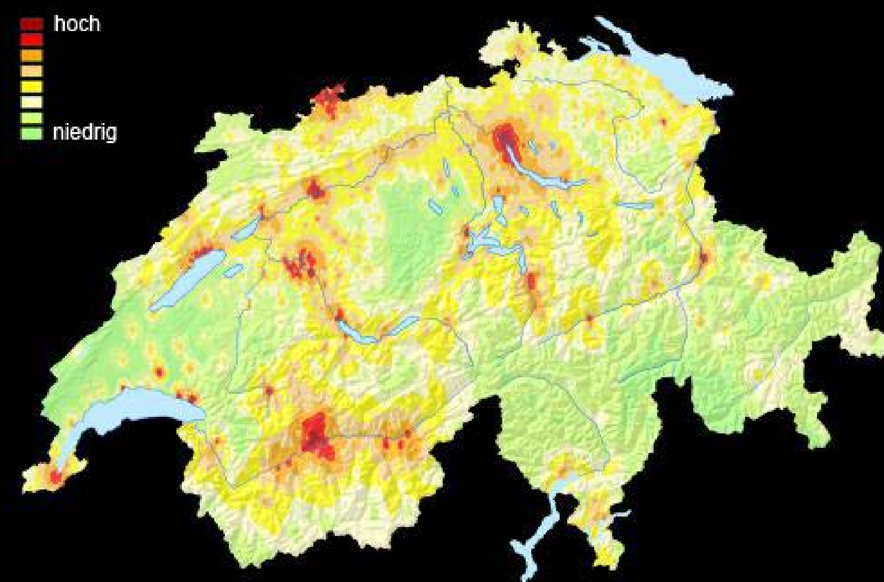
Time-dependent models of earthquake occurrence are based on the assumption that the probability of occurrence of an earthquake in a given time period follows a renewal model, in which the probability of the event depends on the time since the last event



http://www.efehr.org:8080/jetspeed/portal/default-page.psml



Erdbebengefährdung in der Schweiz:
rot: hohe Gefährdung, blau/grün: moderate Gefäh



Verteilung des finanziellen Erdbebenrisikos (Quelle: CatFocus PartnerRe)

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The hazard depends on the magnitudes and locations of likely earthquakes, how often they occur, and the properties of the rocks and sediments that earthquake waves travel through.

In particular the last part of the path of the seismic wave is characterized by very local properties.

For this reason maps are often computed for rock and a specific coefficient is applied to take into account the local variability.

This coefficient is very strictly linked to what we call site-effects.

What are the site effects ?

Turkey, August 17th 1999, magnitude 7.4 / 7.5 Mw

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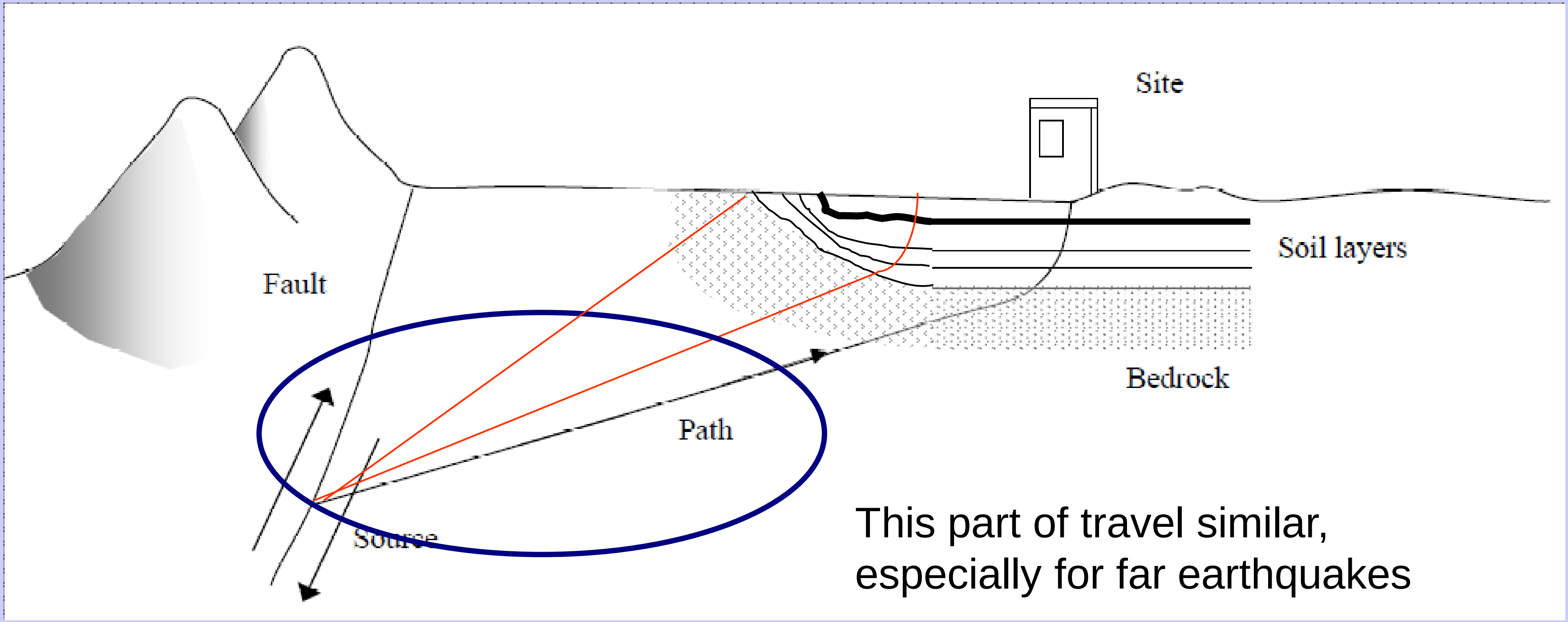
Buildings with similar characteristics experienced different damages.

Niigata, Japan, 1964 magnitude 7.5

All these effects are due to what we call "site effects"

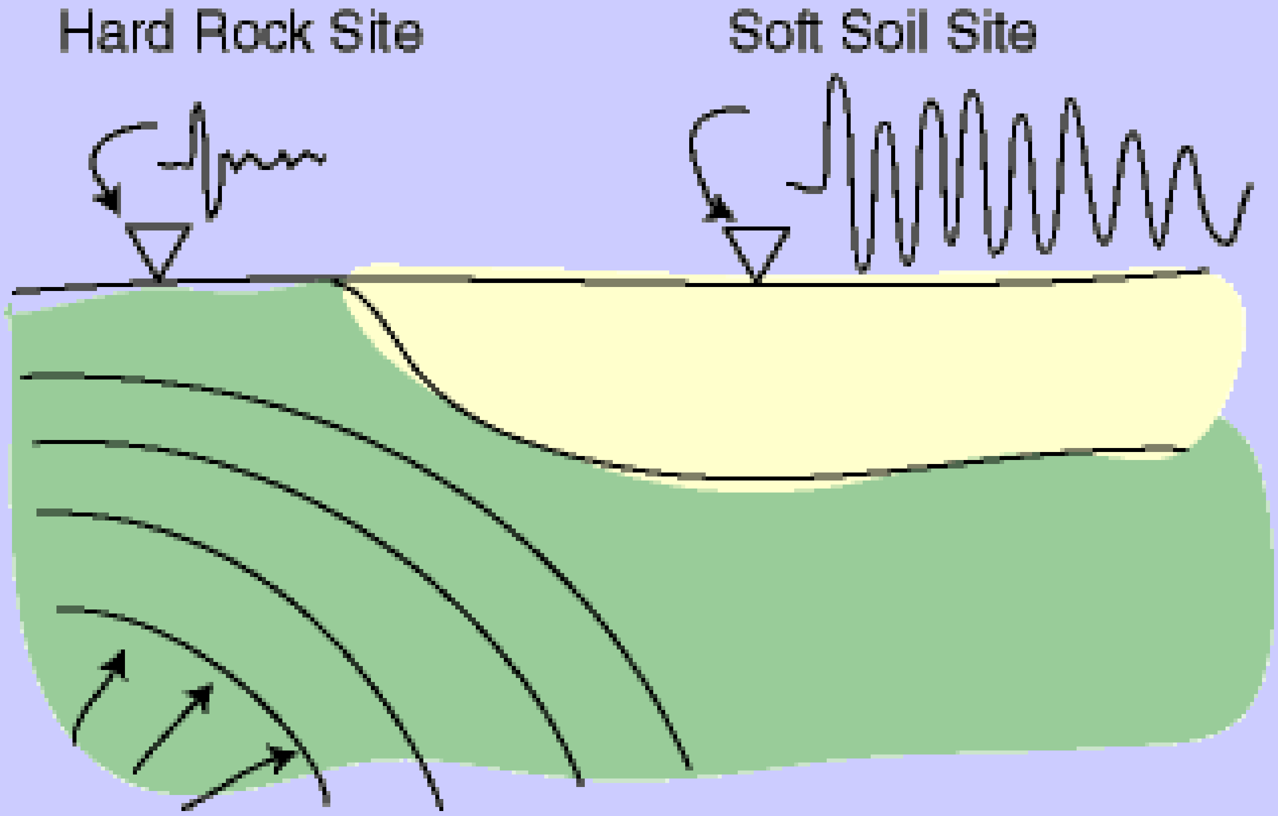
What are the site effects ?



Where do site effects come from…

Redrawn from
Site effects on ground motion
Ioannis N. Psycharis

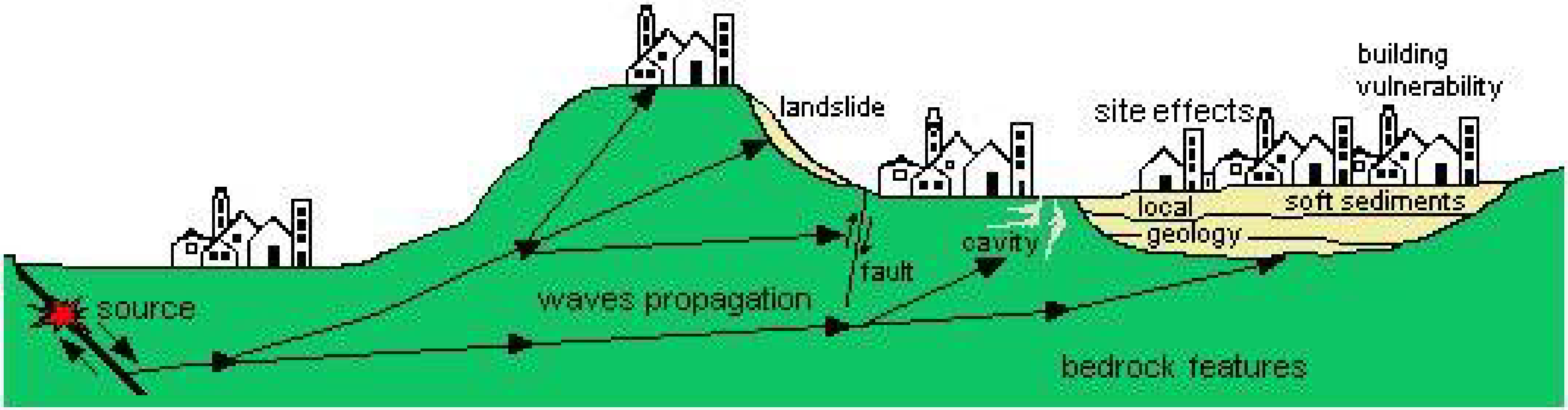
What are the site effects ?



We observe amplification
on the seismic signal

Source: eqseis.geosc.psu.edu

What are the site effects ?



The modifications of seismic waves due to local geological conditions are known as **site effects**, and they can strongly influence the nature and severity of shaking at a given site. Site effects include the following five factors.

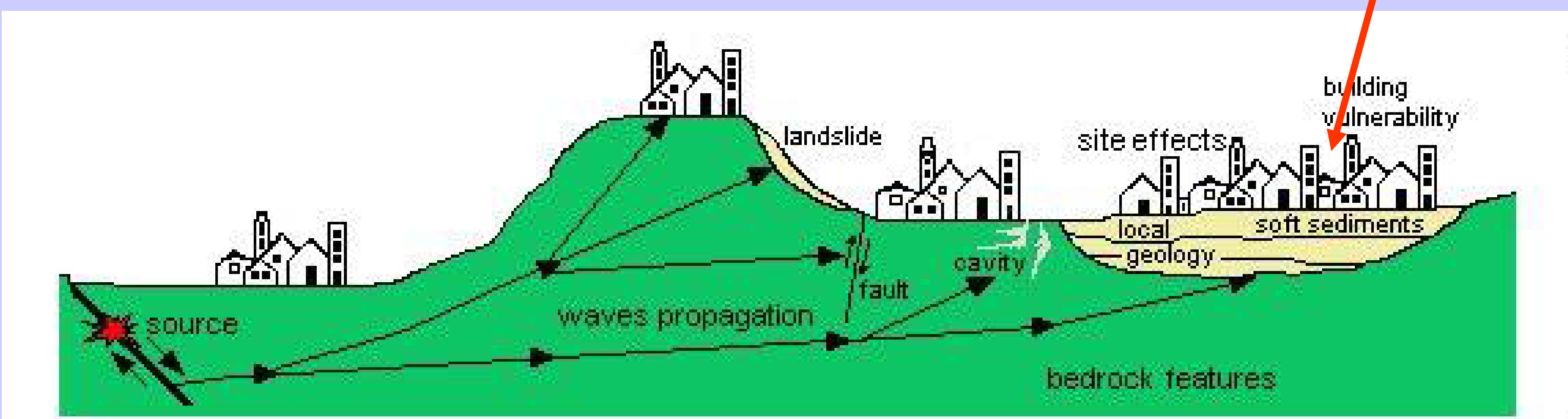
Speedy Techniques to Evaluate Seismic Site Effects in Particular Geomorphologic Conditions: Faults, Cavities, Landslides and Topographic Irregularities

F. Panzera, G. Lombardo, S. D'Amico and P. Galea

What are the site effects ?

1) The softness of the soil or rock beneath a site.

The elastic properties of Earth materials ranges from hard (difficult to deform--think granite) to soft (relatively easy to deform--think mud). Seismic waves travel faster through hard rocks than through softer rocks and sediments. As the waves pass from deeper harder to shallow softer rocks they slow down and get bigger in amplitude as the energy piles up. The softer the rock or soil under a site is, the larger the wave. Softer soils amplify ground motion.

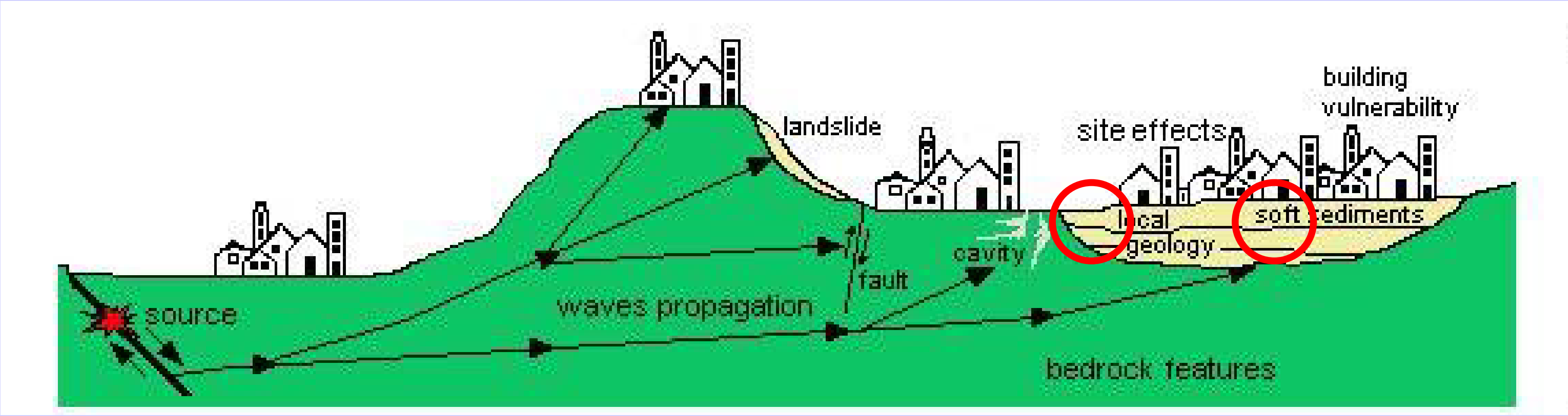


Source: http://www.pnsn.org/outreach/earthquakehazards/site-effects

What are the site effects ?

2) The total thickness of soil to bedrock.

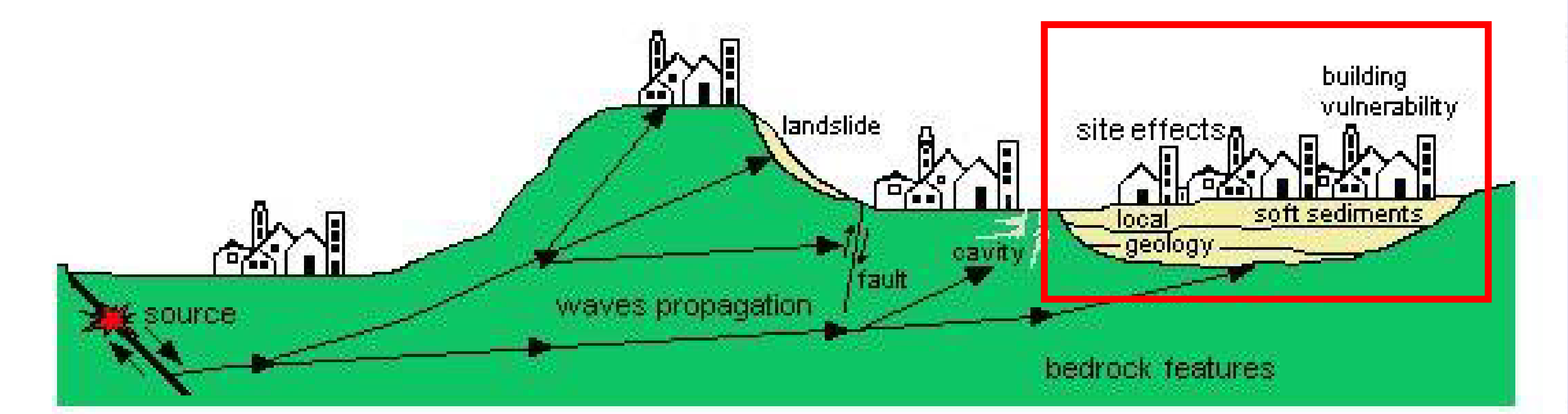
Related to the direct amplification effects of soft Earth materials, the geometry of the soft deposits can further distort ground motion at soft rock sites. Seismic waves entering sediment-filled valleys can trap seismic energy such that it reverberates like sound in an echo chamber. This can lead to both higher amplitudes and longer durations of shaking. Because such effects are geometric in nature, they depend on the characteristics of the incoming wave, and it's direction of approach...they can be very difficult to predict.



What are the site effects ?

3) Sedimentary basins (deep geologic structure)

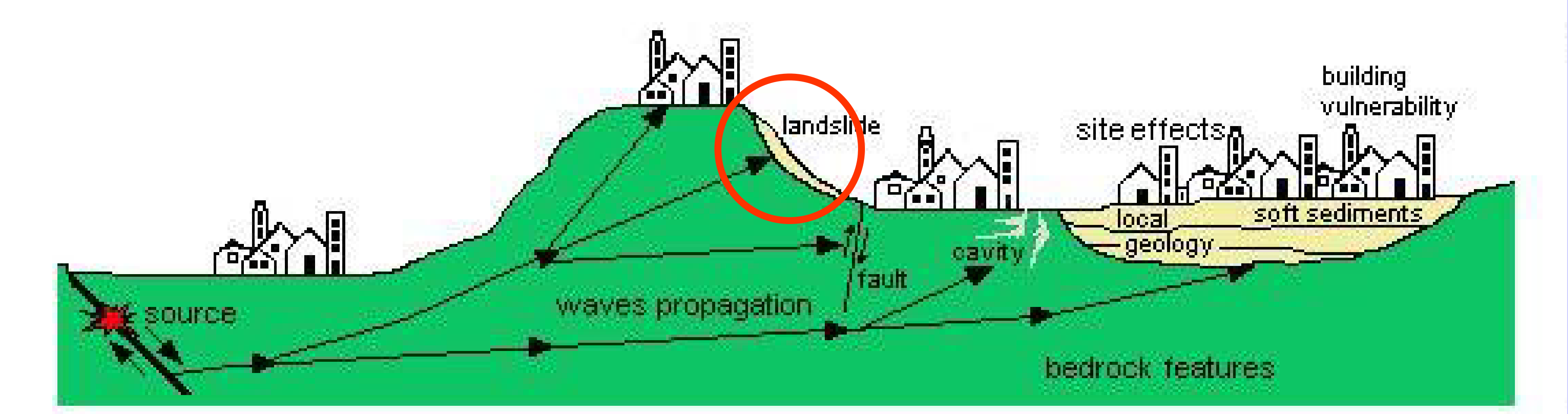
This is essentially the same process before described, but at a broader scale. As such, it impacts the lower frequency seismic waves, and can have more widespread effects and influence larger structures that tend to be more sensitive to low-frequency motions. Deep sedimentary basins can have a large effect on ground motion above them. Earthquake waves traveling at high velocity through the stiff, crystalline rock of the crust refract and slow dramatically when entering the basin. This increases the amplitude of the earthquake waves, and the sharp density contrast of the soft basin rocks with surrounding material can cause waves to reflect, trapping energy in the basin for a period of time. This extends the duration of shaking. Due to their size, these deep geologic structures can influence shaking over a wide area.



What are the site effects ?

4) Ground failure potential (Liquefaction and Landslides).

Ground failures can be as spectacular as a large landslide or much more subtle where sub-surface liquefied soils lead to differential settlement of a structure above, but the results of both types of failure can lead to large losses.

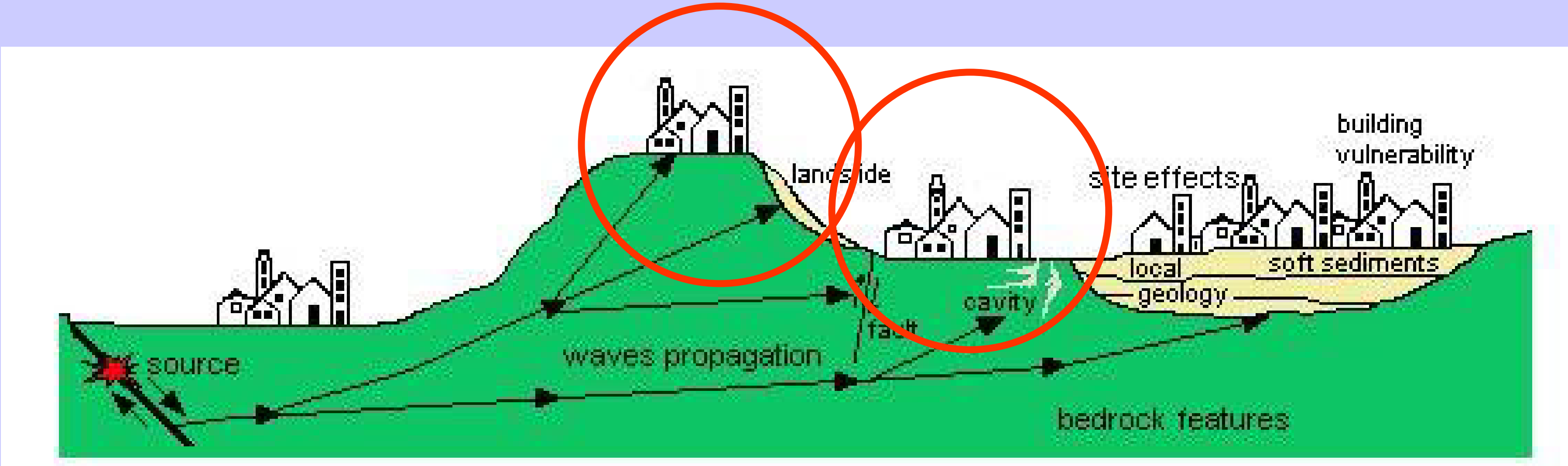


Christchurch, 22 February 2011

What are the site effects ?

5) Topography

The features present at the Earth's surface have also been identified as having an influence on shaking intensity. Some studies of the distribution of the intensity of shaking experienced in an earthquake concluded that hilltop sites often shook at one intensity level higher than nearby sites with flatter topography.



…..really ?

How do we measure / quantify site effects ?

Measuring them.

➢ *By installing acceleration sensors and waiting for earthquakes to occur*

➢ *By measuring, through geophysical methods, dynamic characteristics of soil deposits*

Modeling them.

➢ *This, of course, requires detailed knowledge and expert criteria*

Ground type and description	$v_{s,30}$	N_{SPT}	c_u
A: Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface.	>800	-	-
B: Deposits of very dense sand, gravel, or very stiff clay, at least several tens of meters in thickness, characterized by a gradual increase of mechanical properties with depth.	360-800	>50	>250
C: Deep deposits of dense or medium dense sand, gravel or stiff clay with thickness from several tens to many hundreds of meters.	180-360	15-50	70-250
D: Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil.	<180	<15	<70
E: A soil profile consisting of a surface alluvium layer with *v*s values of type C or D and thickness varying between about 5 m and 20 m, underlain by stiffer material with *v*s > 800 m/s.			
S_1: Deposits consisting, or containing a layer at least 10 m thick, of soft clays/silts with a high plasticity index (PI > 40) and high water content	<100	-	10-20
S_2: Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A – E or S_1			

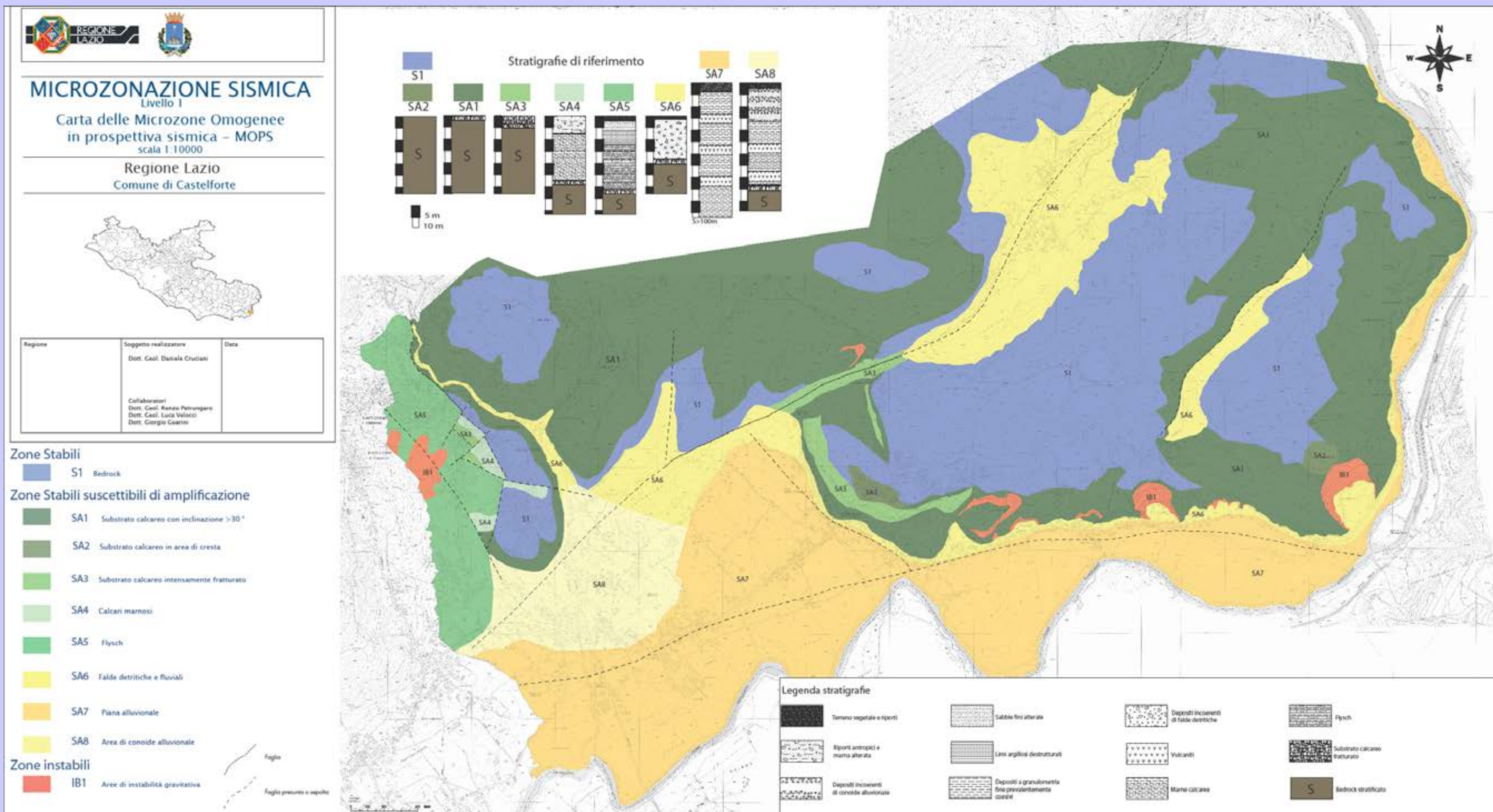
Table 1: Ground types according to Eurocode 8(EC8 § 3.1.2 Table 3.1)

Vs30 is the average velocity of the shear wave velocity in the first 30 mt

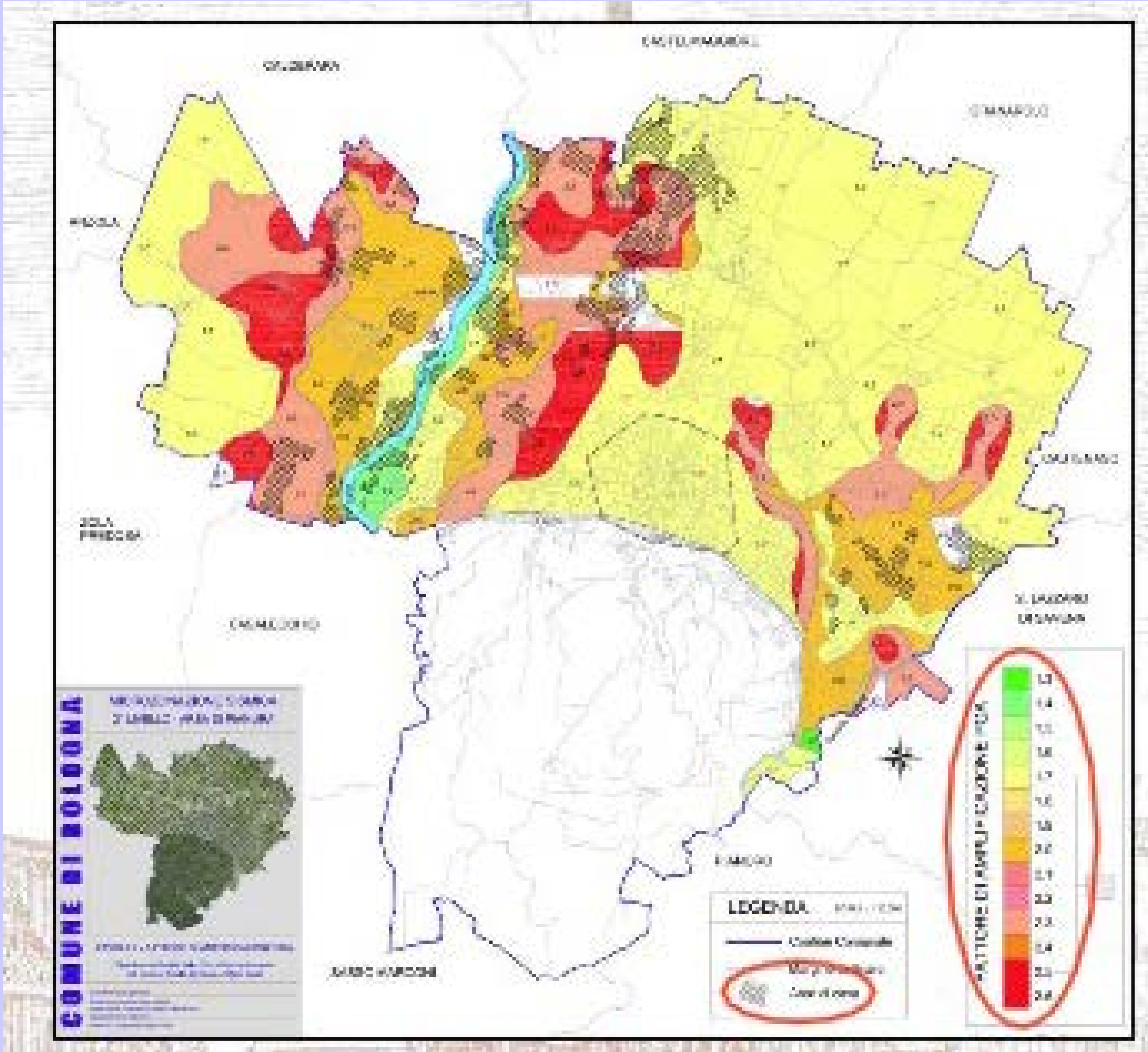
How do we measure / quantify site effects ?

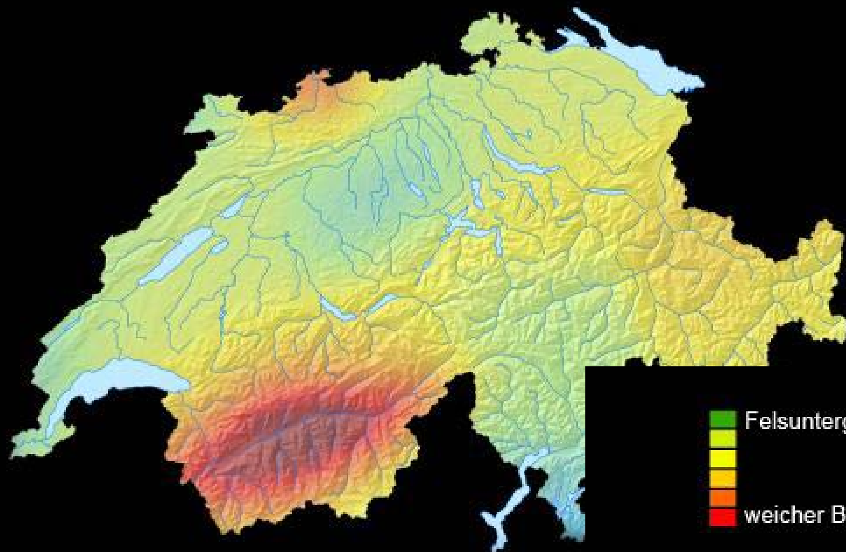
All information about local effects concur to special maps (microzonation).

In general it is required to have information about the deep (and 3D) geology

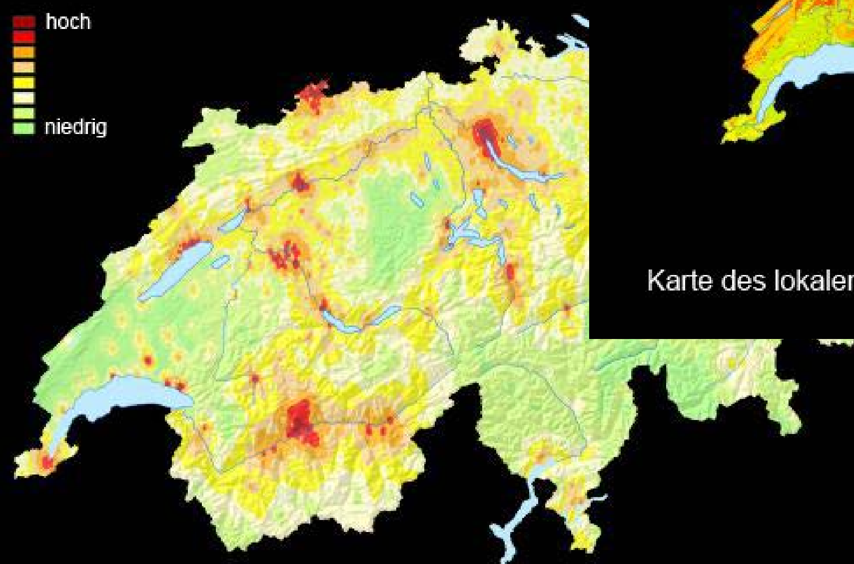


and more quantitative measurements and maps

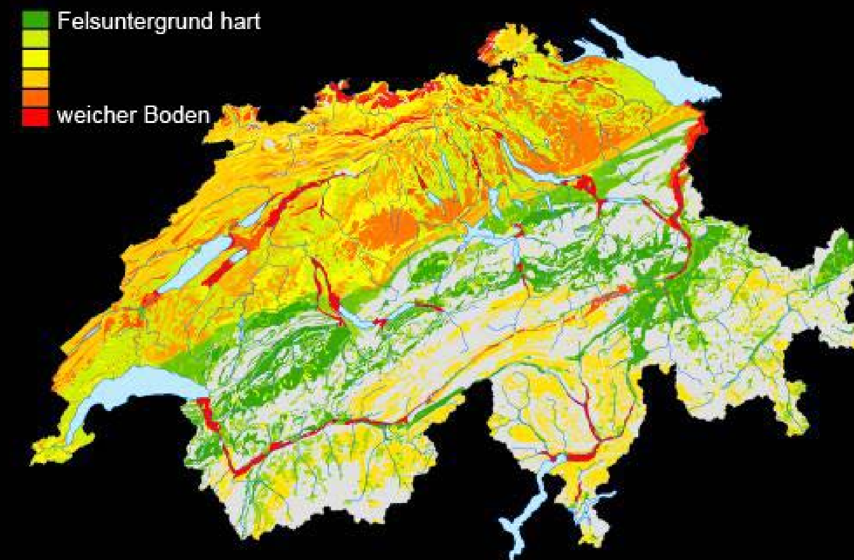




Erdbebengefährdung in der Schweiz:
rot: hohe Gefährdung, blau/grün: moderate Gefährdur



Verteilung des finanziellen Erdbebenrisikos (Quelle: CatFocus PartnerRe)



Karte des lokalen Untergrundes. Besonders gefährdete Gebiete sind rot markiert.

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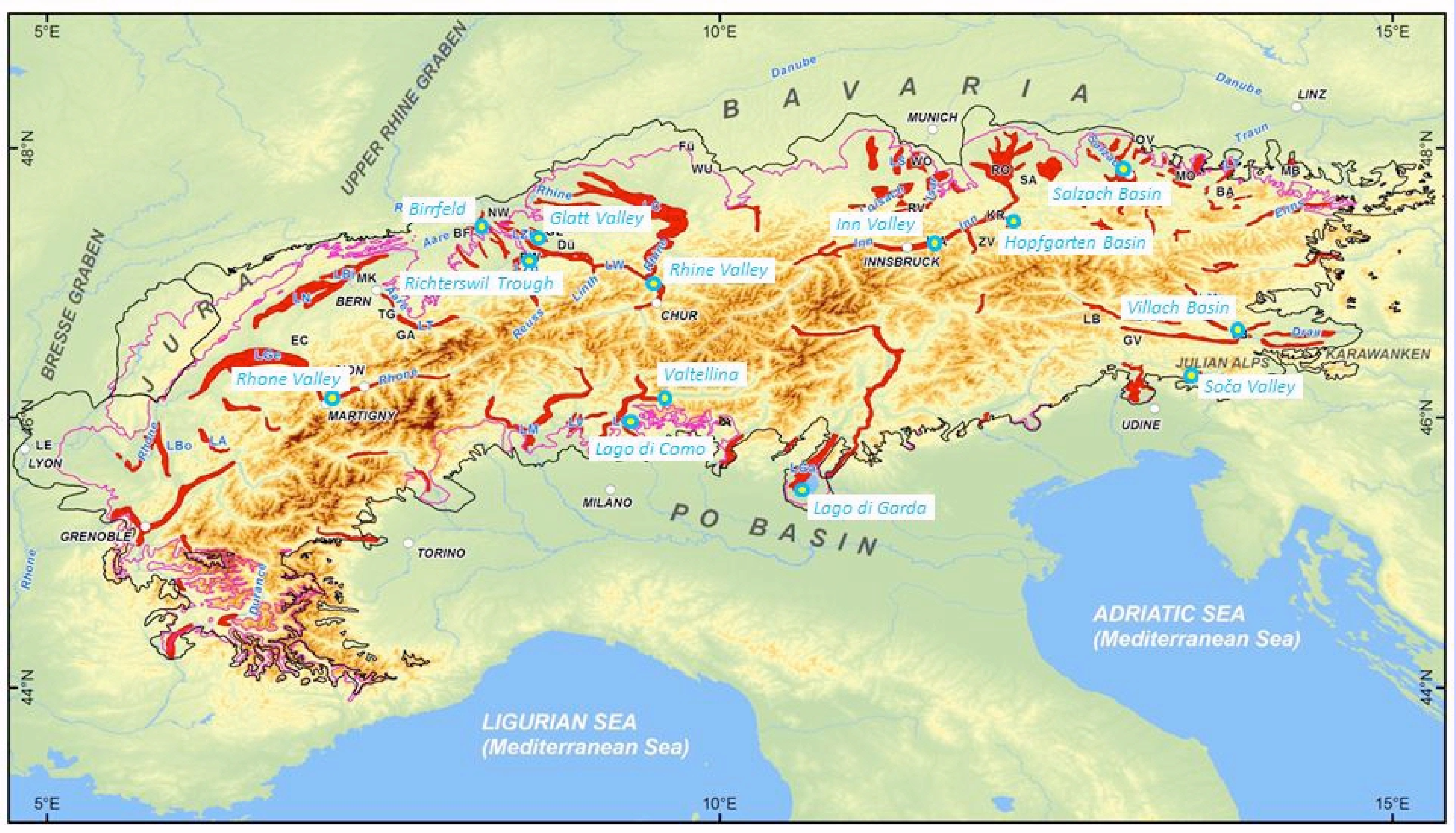
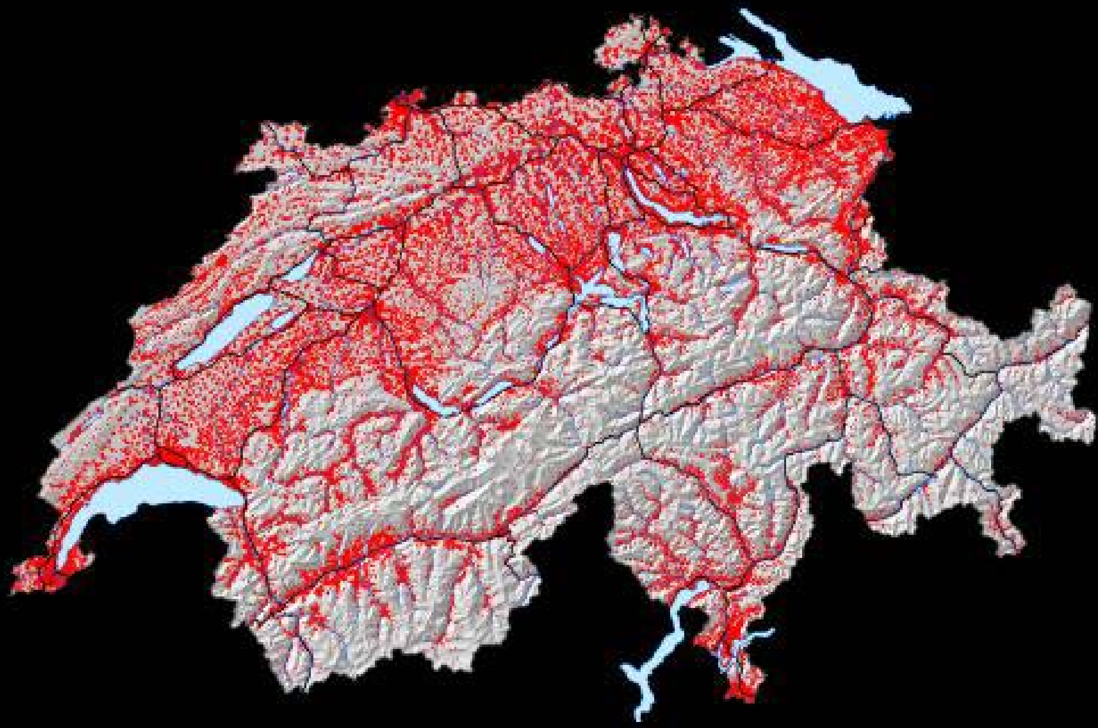
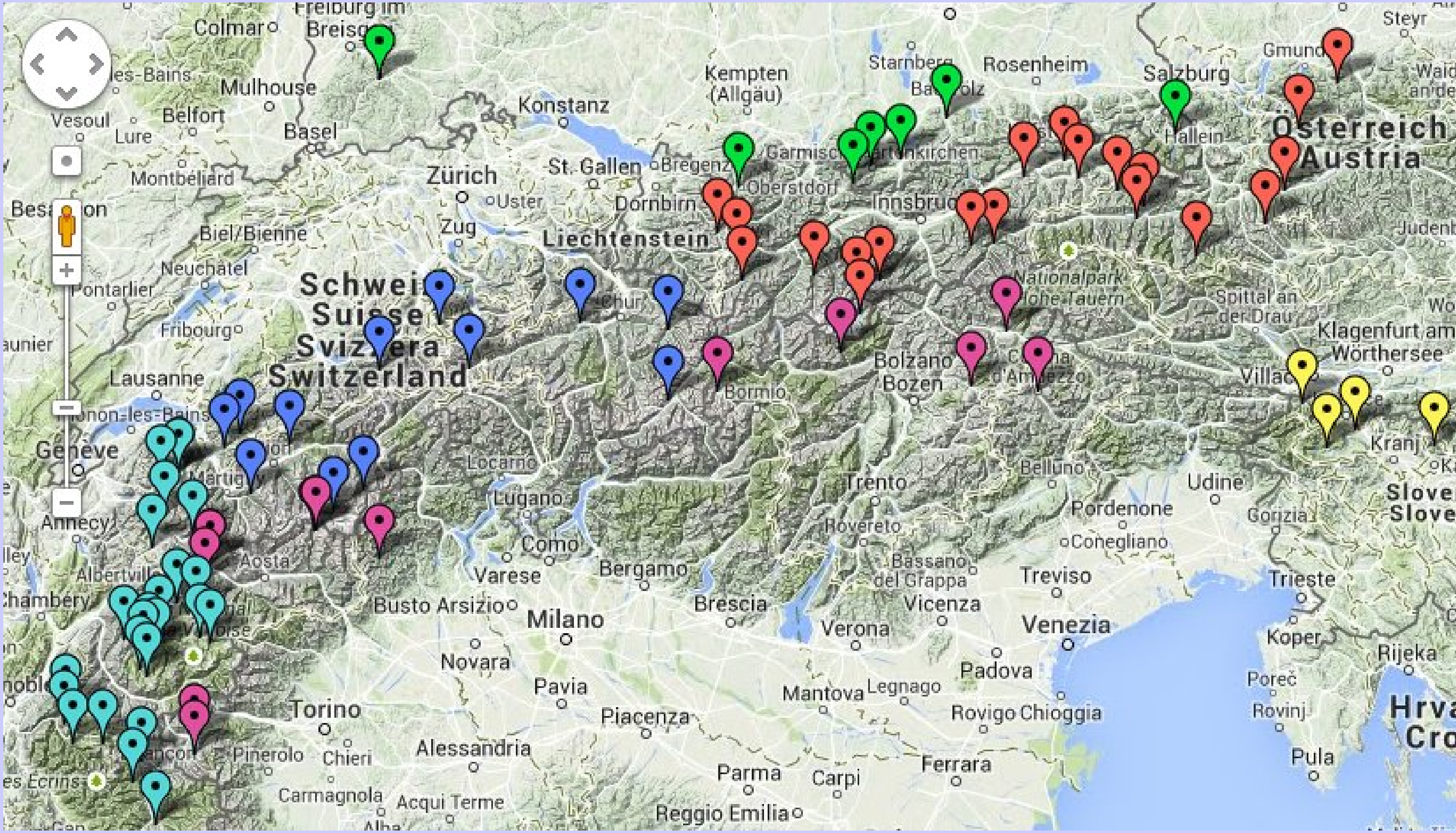
CONCLUSIONS



Site effects



Verteilung der Siedlungen in der Schweiz



Maps of the main ski resorts in the Alps

Exposure

Infrastructures: main road across countries

Exposure

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