Seismic hazard analysis for Nuclear Power Plants (NPP)

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APAT

Agency for Environmental Protection and Technical Services

SITING

The process of selecting a suitable location for any type of facilities based on appropriate assessment and definition of the design parameters, in order to protect the facility from environmental hazards and to minimize the impact of the plant to the environment.

DESIGN BASIS EXTERNAL EVENTS

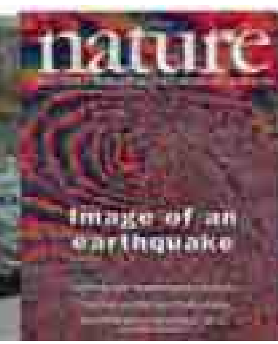
The numerical values characterizing the selected natural event (e.g. PGA and response spectrum for EQ).

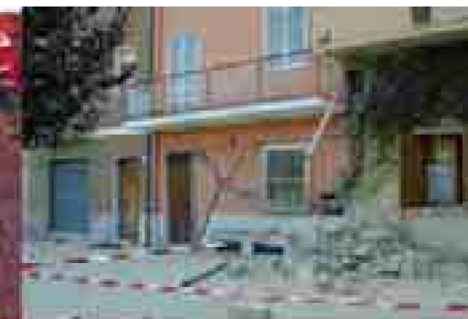
Scheme of presentation

FIRST PART

Major natural processes important for siting and their impact on human works.

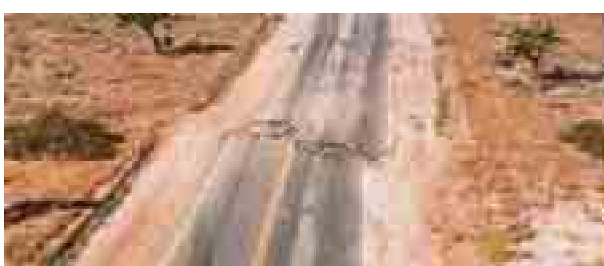


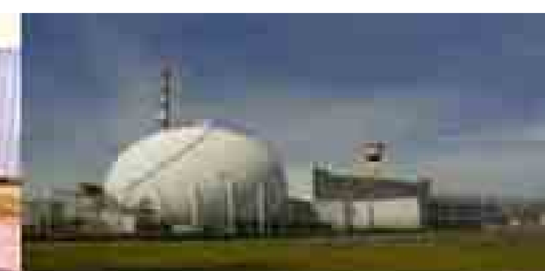




SECOND PART

The example of sesmic hazard in siting procedure for nuclear power plants.





Introduction: variability of natural phenomena

- Natural environment is strongly variable and heterogeneous.
- This variability in scale is clearly evident in each component of natural environment including morphogenetic processes.
- Geological processes are characterized by an extreme variability in scale. They may occur gradually as well instantaneously.
- Landscape is mainly the result of “extreme” events which model the territory and are often dramatic for anthropic environment.

Introduction: variability of natural phenomena

- The variability of parameters describing natural phenomena may be of more than 10 orders.
- This extreme variability is in magnitude as well as in time.

$\Downarrow$

It is very difficult to define univocally what are the main elements from the engineering point of view.

Introduction: variability of natural phenomena

Changes from a standard state to extreme conditions typically occur very fast

STANDARD

- Rainfall
- River water discharge
- Slow slope deformations
- Stress accumulation

MAY EVOLVE VERY FAST TO

EXTREME

- Extreme meteorological events
- 10^2 - 10^4 increasing
- Rapid gravitational movement
- Instantaneous rupture (earthquake)

Introduction: variability of natural phenomena

- In case the impact of a natural phenomenon not compatible with site stability is not adequately characterized, change from standard to extreme conditions makes impossible the adoption of mitigation and/or adaptation measures during or after the extreme event.

Order of magnitude	10 E	10	8	6	4	2	0	- 2	- 4	- 6	- 8	- 10
Time scale of geological processes	*y*											
Released energy from earthquake	*MJ*											
Coseismic surface faulting	*mm*											
Subsidence rate	*mm/y*											
Rate of gravitational phenomena	*m/s*											
Volume of landslides	*m^3*											
Density of landslides for intense rainfall	*n/ km^2*											
Recurrence time for activation of landslides	*y*											
Daily rainfall	*mm*											
Daily snowfall	*mm*											
Rainfall rate	*mm/h*											

Scale of geological phenomena

Major natural processes important for siting

- Flooding
- Erosion and sedimentation
- Landsliding
- Surface faulting
- Ground motion
- Subsidence
- Expansive soils
- High-water table
- Seacliff retreat
- Beach destruction
- Migration of sand dunes
- Salt-water intrusion
- Liquefaction

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FLOODING 15.10.2000 Northern Italy

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Impact on human works by flooding

Impact on human works by flooding

Impact on human works by flooding

Impact on human works by seismically induced flooding

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Impact on human works by erosion

15.10.2000 Valle d’Aosta (Northern Italy)

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Landsliding

04.05.1998 Sarno (Southern Italy)

Landsliding

04.05.1998 Sarno
(Southern Italy)

Impact on human works by landsliding

15.10.2000

Valle d’Aosta

(Northern Italy)

Impact on human works by landsliding

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Valle d'Aosta (Northern Italy)

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Surface faulting

07.12.1988

M = 6.8

Spitak

(Armenia)

Surface faulting

13.01.1915

M = 6.9

Fucino

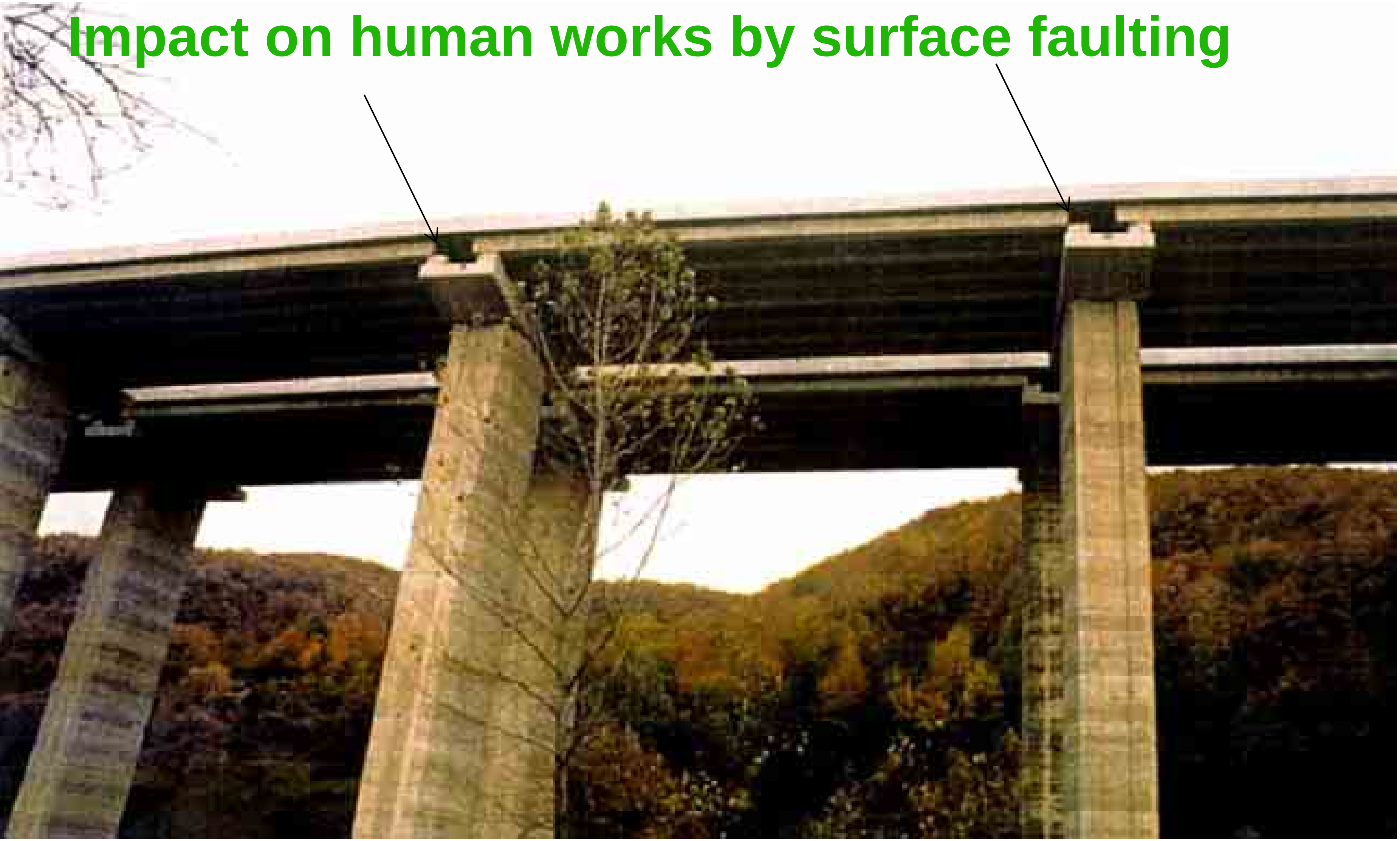
(Italy)

Impact on human works by surface faulting

Sea of Marmara 1999 earthquake

Effects of surface faulting on the 2 m water pipeline

Impact on human works by surface faulting



Sea of Marmara, 1999 earthquake Effects of surface faulting on the viaduct

Impact on human works by surface faulting

28.06.1992

M = 7.3

Landers

(USA)

Major natural processes important for siting

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Ground motion

28.06.1992 M = 7.3

Landers (USA)

Impact on human works by ground motion

31 Oct. 2002 Ml = 5.4 Molise (Italy)

Impact on human works by ground motion

31 Oct. 2002 Ml = 5.4 Molise (Italy)

Major natural processes important for siting

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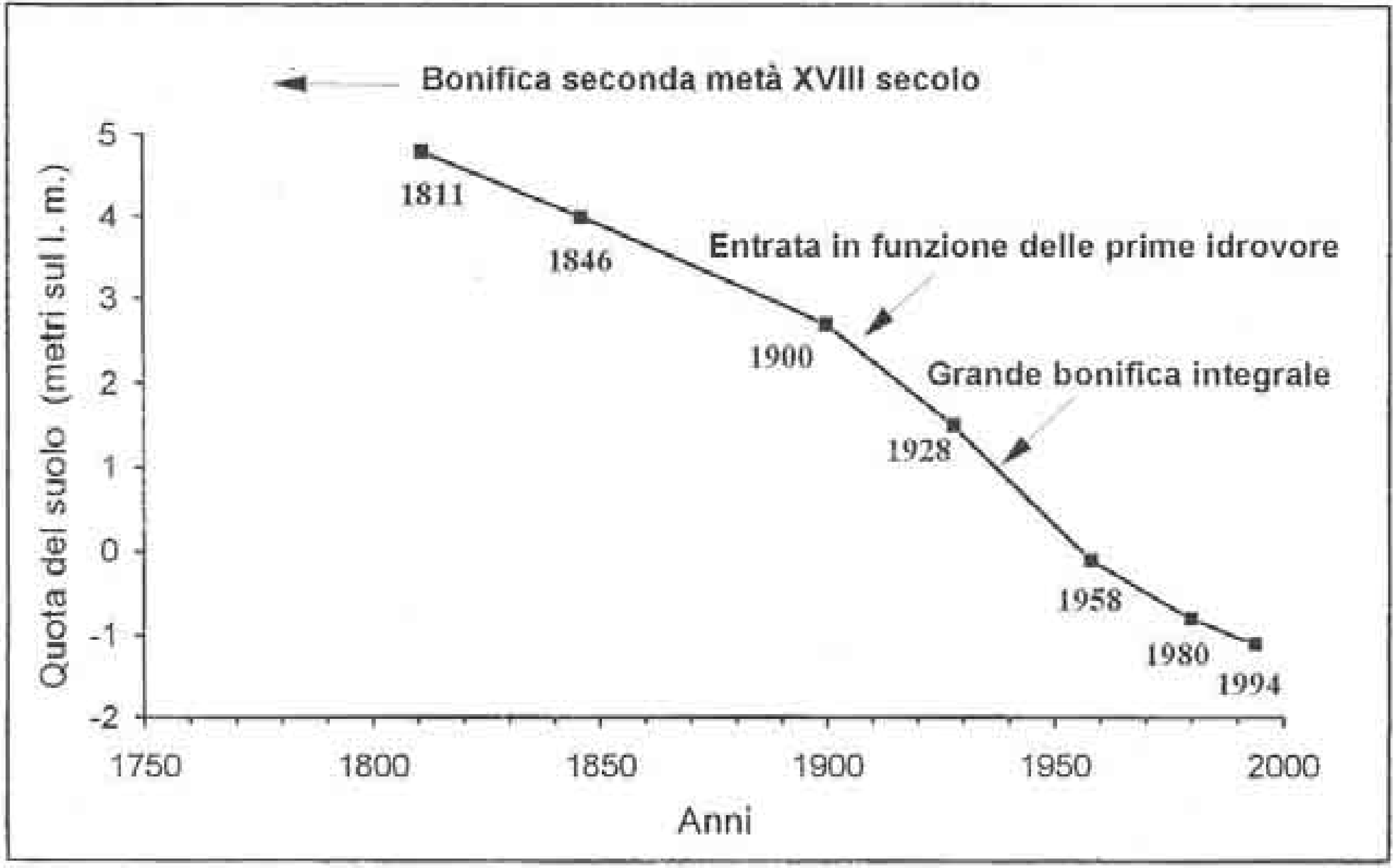
Impact on human works by Man-induced land subsidence

Pontina Plain (Italy) Reclamation works

Impact on human works by Man-induced land subsidence

Impact on human works by Man-induced land subsidence



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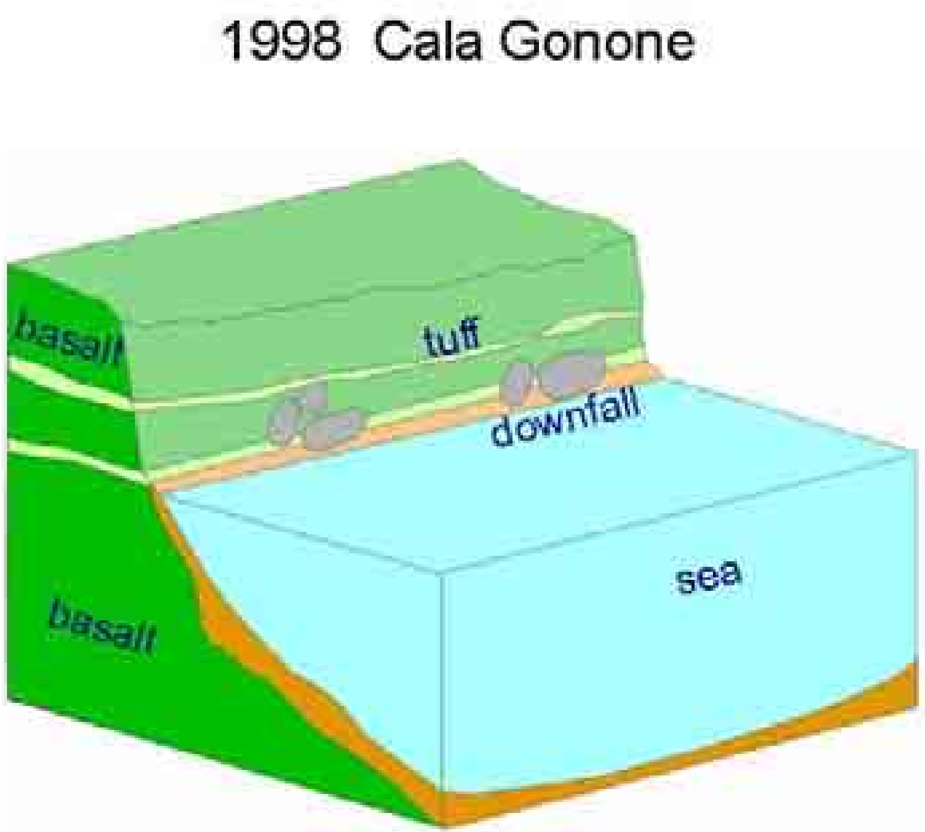
Seacliff retreat

Impact on human works by seacliff retreat



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Beach destruction

September 2002

Elba Island (Italy)

Beach destruction

September 2002 Elba Island (Italy)

Major natural processes important for siting

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Coseismic liquefaction

23 Nov. 1980 M = 6.9 Irpinia (Italy)

Coseismic liquefaction

Nov. 2004 M = 5.5 Garda (Italy)

Impact on human works by coseismic liquefaction

Mexico City

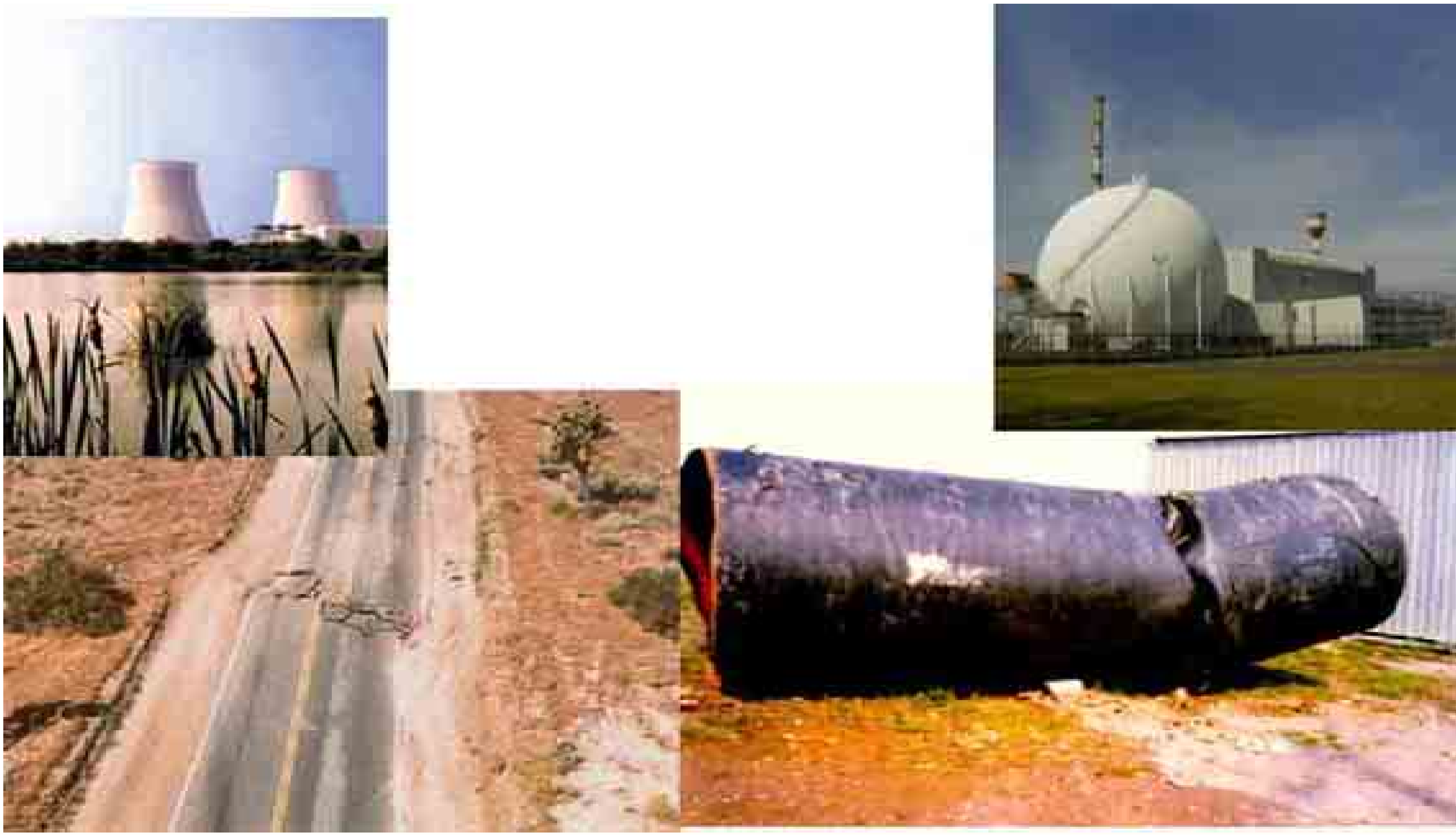
1985

earthquake

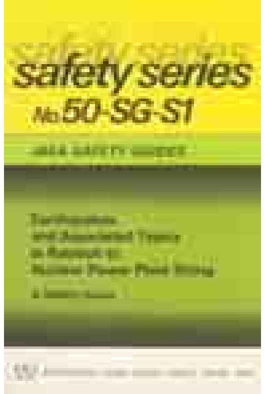
Impact on human works by coseismic liquefaction

Impact on human works by coseismic liquefaction

Seismic hazard analysis for Nuclear Power Plants (NPP)



Geologic hazards connected with seismic phenomena to be considered in npp siting procedures



(described in the IAEA Safety Guide 50 SG, 1991)
(International Atomic Energy Agency)

- Faults
- Vibratory ground motion from earthquakes
- Stability of foundation materials (static and dynamic cond.)
  - *Strength of foundation materials*
  - *Loss of strength or stability during life of plant*
  - *Existing or potential subsurface cavities*
  - *Subsidence from mining or from withdrawal of fluids*
- Landslides
- Tsunamis
- Flooding related to dams usptream from a site
- Sismo-volcanic hazards
- Ground water (in relation to uplift on structures and liquefaction of soils

First category of investigations: Characterization of class 1 features

CLASS 1 (earthquake-related) FEATURES: geological and/or geotechnical elements having a direct impact on the designed site and that can have direct influence on the acceptability of the site (capable faults, large landslides, liquefaction phenomena, karst collapses).

Engineering solutions are not available or the cost of applying them is too high.

INVESTIGATIONS

- Geological and geomorphological mapping
- Topographical analyses
- Geophysical surveys
- Trenching and boreholes
- Local seismological investigations

Second category of investigations:Definition of class 2 features

CLASS 2 (earthquake-related) FEATURES: ground motion parameters that can substantially influnce the severity of the design basis earthquakes, without a direct influence on the acceptability of the site.

Two levels of design basis ground motion

- SL1 reflects more likely earthquake load conditions
- SL2 corresponds directly to ultimate safety requirements (maximum level of ground motions)

INVESTIGATIONS

- Seismological and geological database for the construction of a seismotectonic model from which the potential earthquakes affecting the site can be derived.

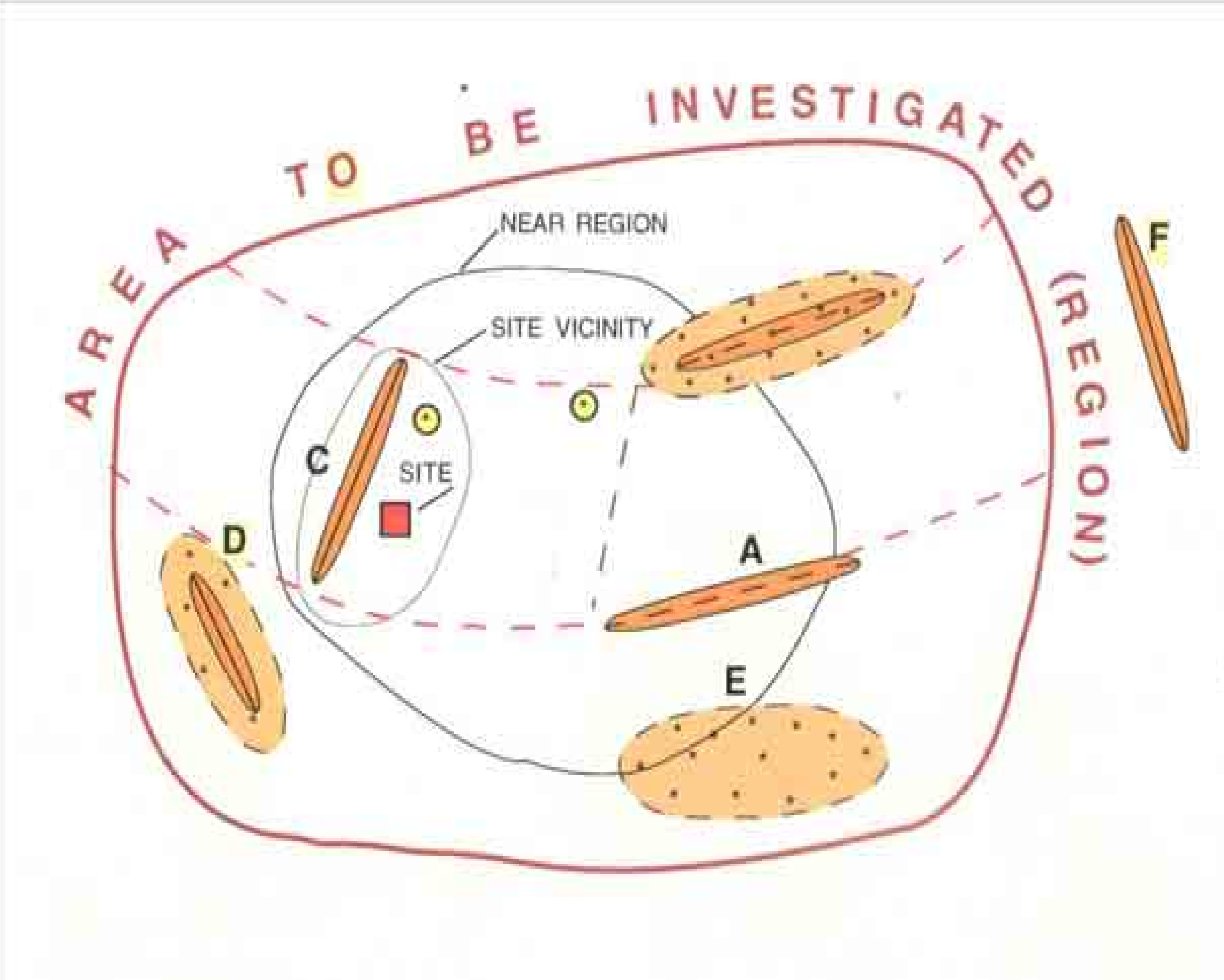
Scales of investigations

- <u>Regional (1:500,000)</u>
  to provide knowledge of the tectonic framework of the region and its general geodynamic setting and characterize those seismogenic features that may influence the seismic hazard at the site.

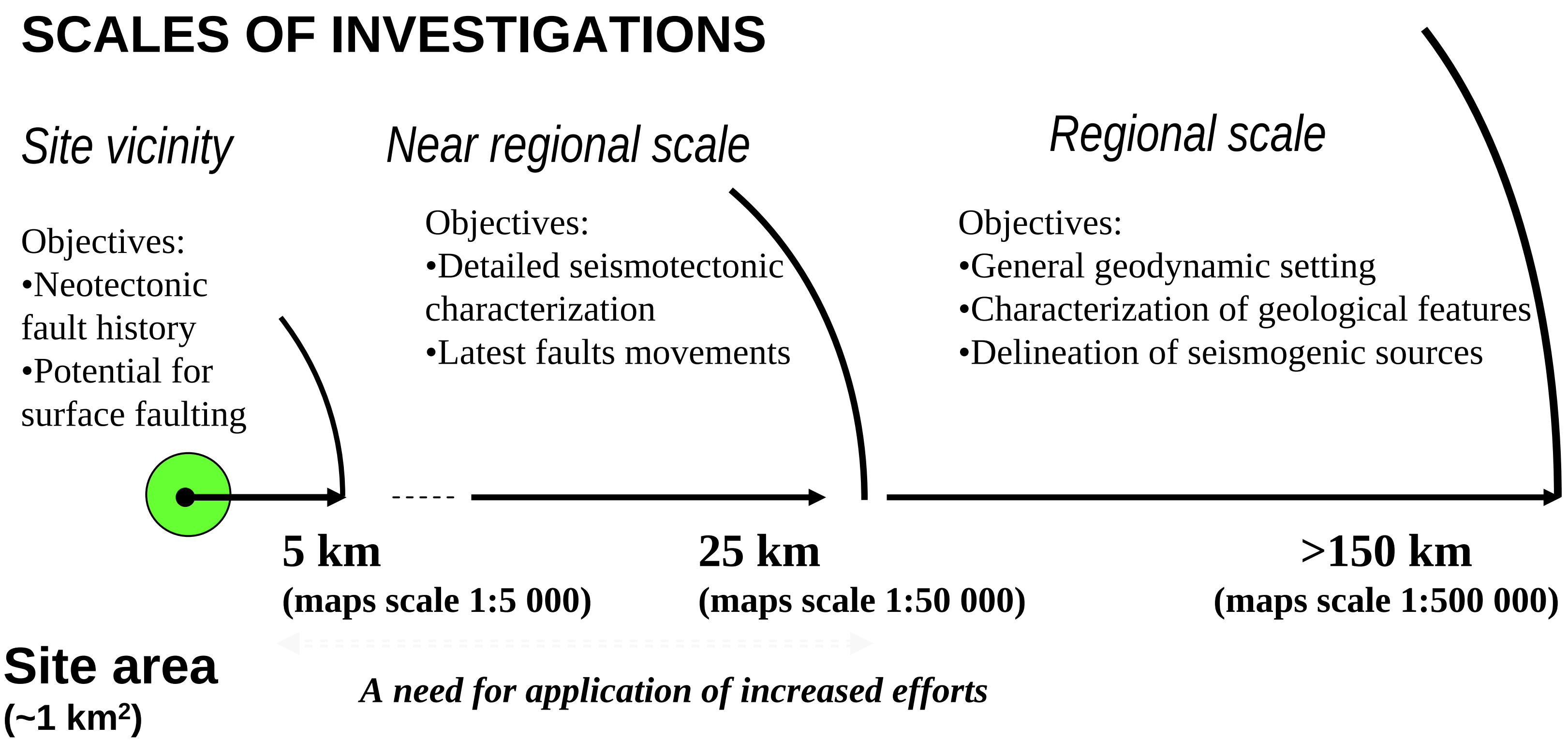
- <u>Near regional (1:50,000)</u>
  to characterize the more important seismogenic structures for the assessment of seismic hazard.

- <u>Site vicinity (1:5,000)</u>
  to define in greater detail the neotectonic history of faults with special purpose of resolving the possibility of surface faulting at the site and identifying sources of potential instability.

- <u>Site area (1:500)</u>
  to define the physical properties of the foundation materials and the stability under dynamic earthquake loading.


AREA TO BE INVESTIGATED (REGION)
NEAR REGION
SITE VICINITY
SITE
A
C
D
E
F

Necessary information and investigations (database)



The first three scales of investigation lead primarily to progressively more detailed geological and geophysical data and information. The site area investigations are aimed at developing the geotechnical database.

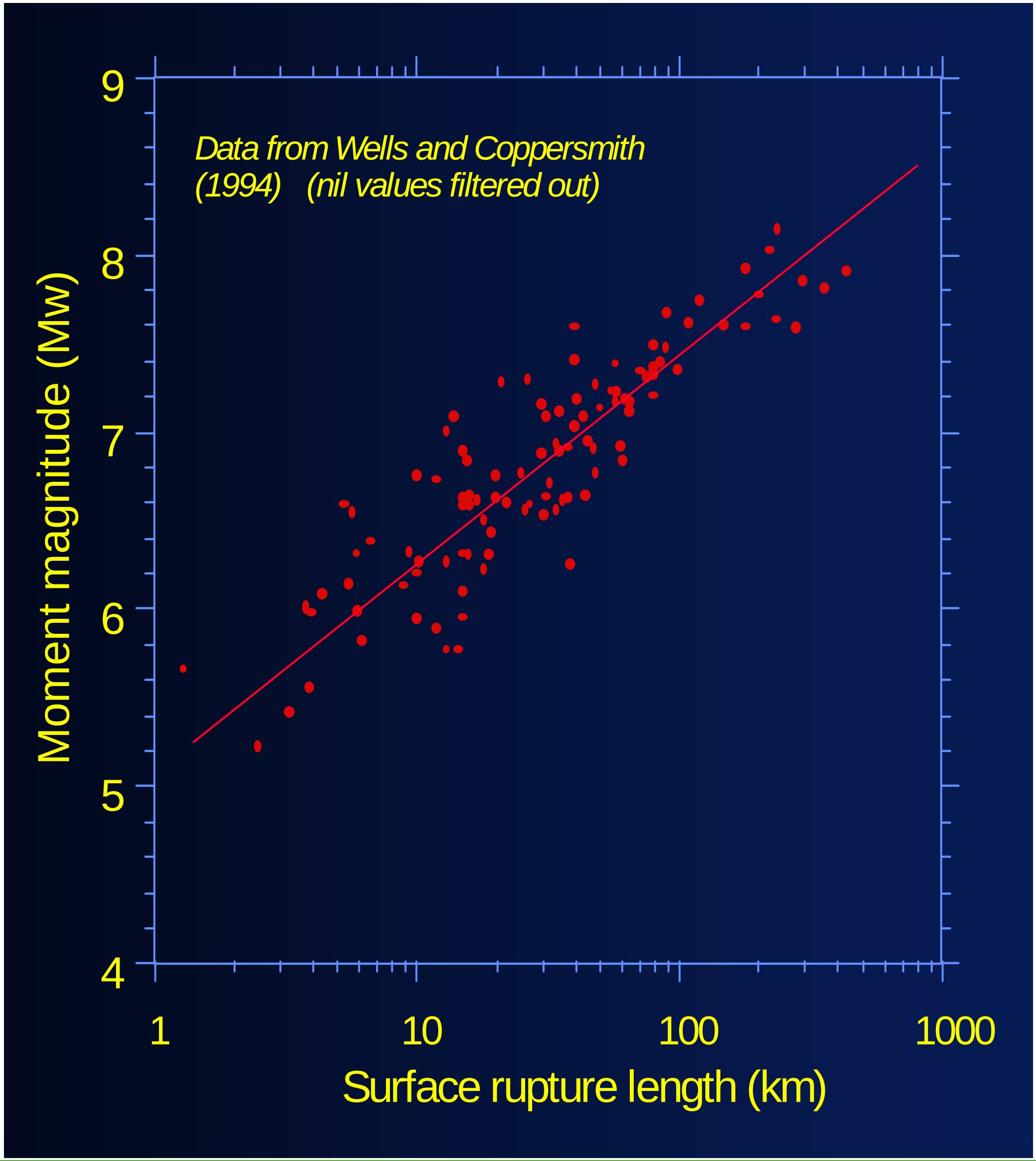
Exclusion criteria and minimum requirements for npp seismic design in various countries

Code	Exclusion criteria	Minimum requirements
IAEA	*	Minimum SL2=0.1 g anchored to a site specific response spectrum
Italy	Area of historically observed intensity equal to X MCS (MMI or MSK) or greater. Presence of capable fault at the site.	Minimum SSE=0.18 g anchored to a wide band standard response spectrum
Former USSR	Sites having a potential for intensity IX MSK or greater. NPP cannot be deisgned for more than 0.2 g. Presence of capable faults. Zones with strain-rate in the crust, recorded by instruments, greater than 5-10 mm/y	Bearing capacity of the foundation soil > 0.2 kg/cm^2
USA	*	Minimum SSE=0.1 g anchored with a wide band response spectrum
Japan	Sites having capable faults or close to faults having a Quaternary slip-rate higher than 1 mm/y.	Foundation must be on sediments not younger than Tertiary. S2 shall withstand a near field earthquake (minimum distance 10 km) having M = 6.5
France	*	*
Germany	Presence of capable fault at the site	Minimum peak ground acceleration = 0.05g
UK	*	*

DESIGN EARTHQUAKE:

surface faulting and magnitude

Magnitude	Surface rupture (km)	Average deformation (cm)
9.00	800	800
8.00	250	500
7.00	50	100
6.00	10	20
5.00	3	5
4.00	1	2



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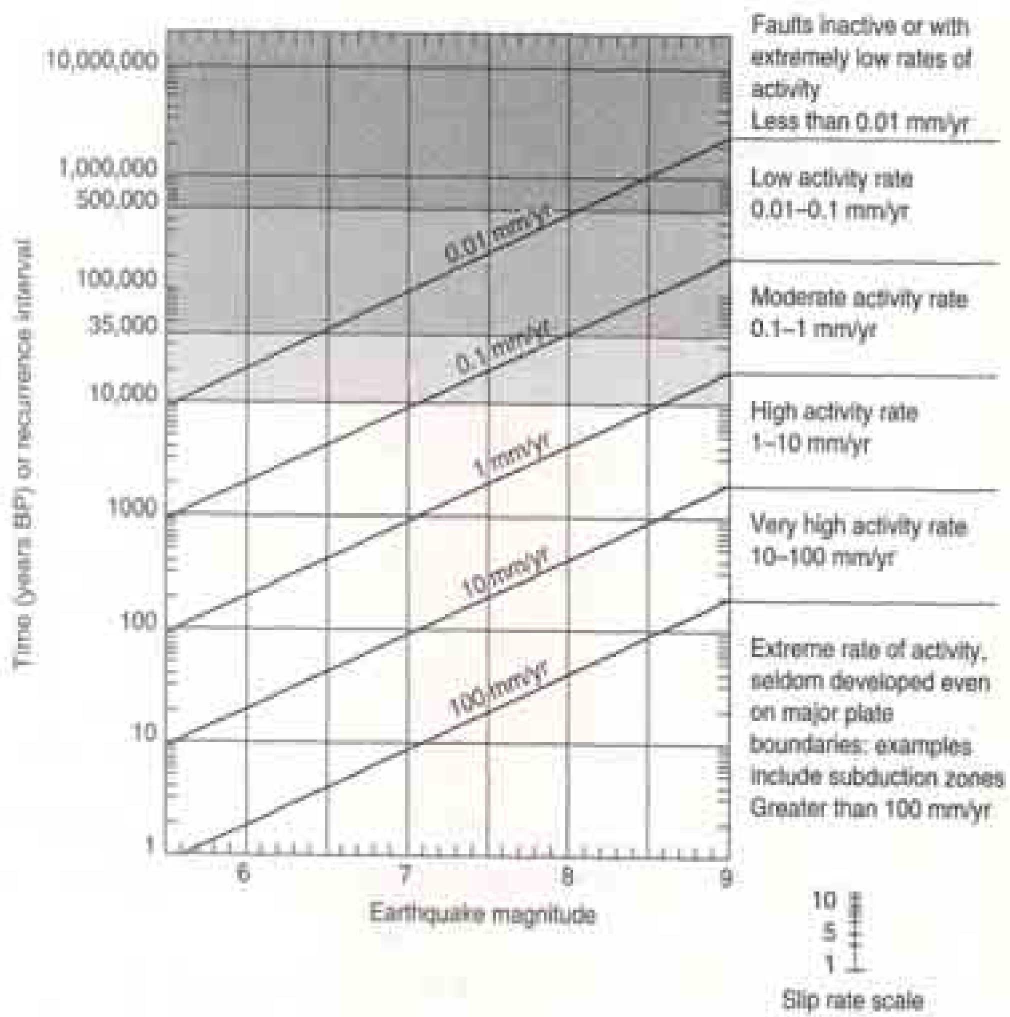

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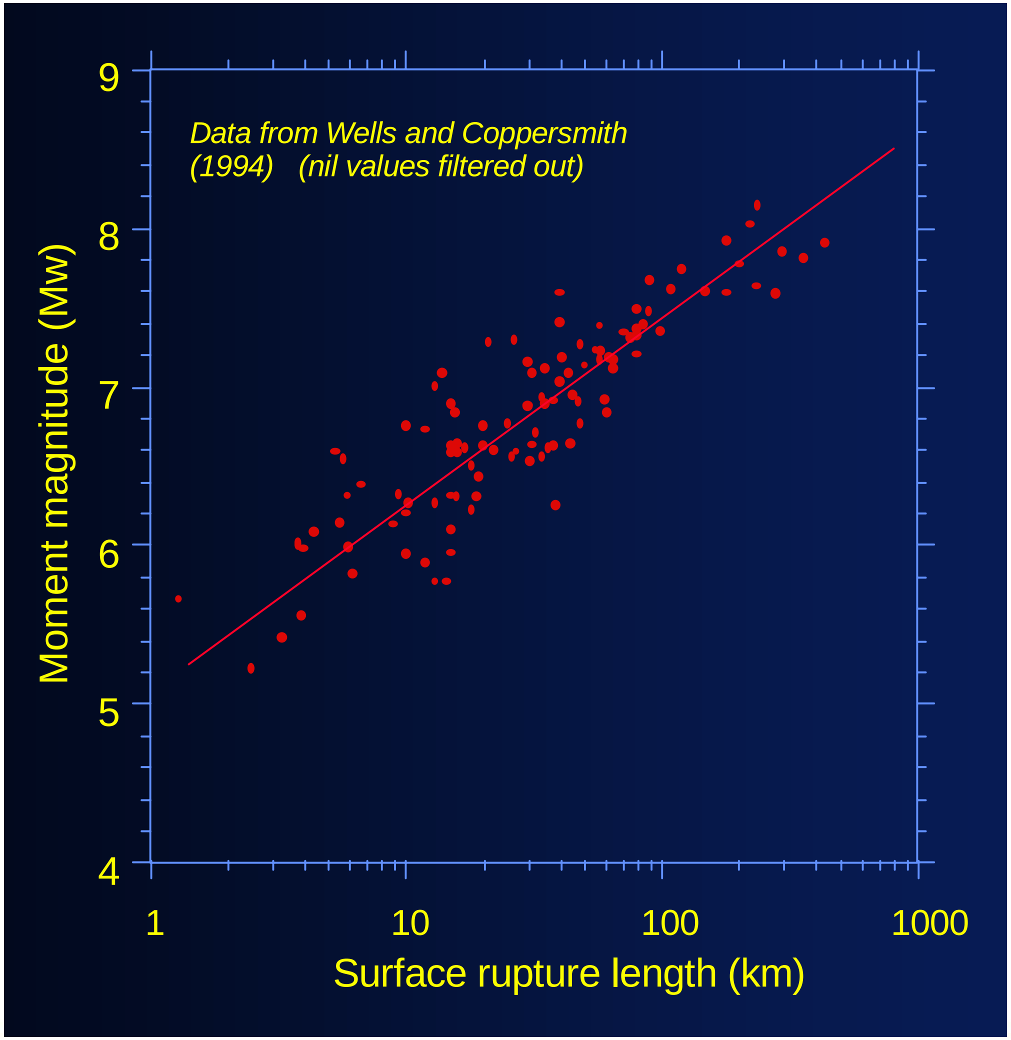

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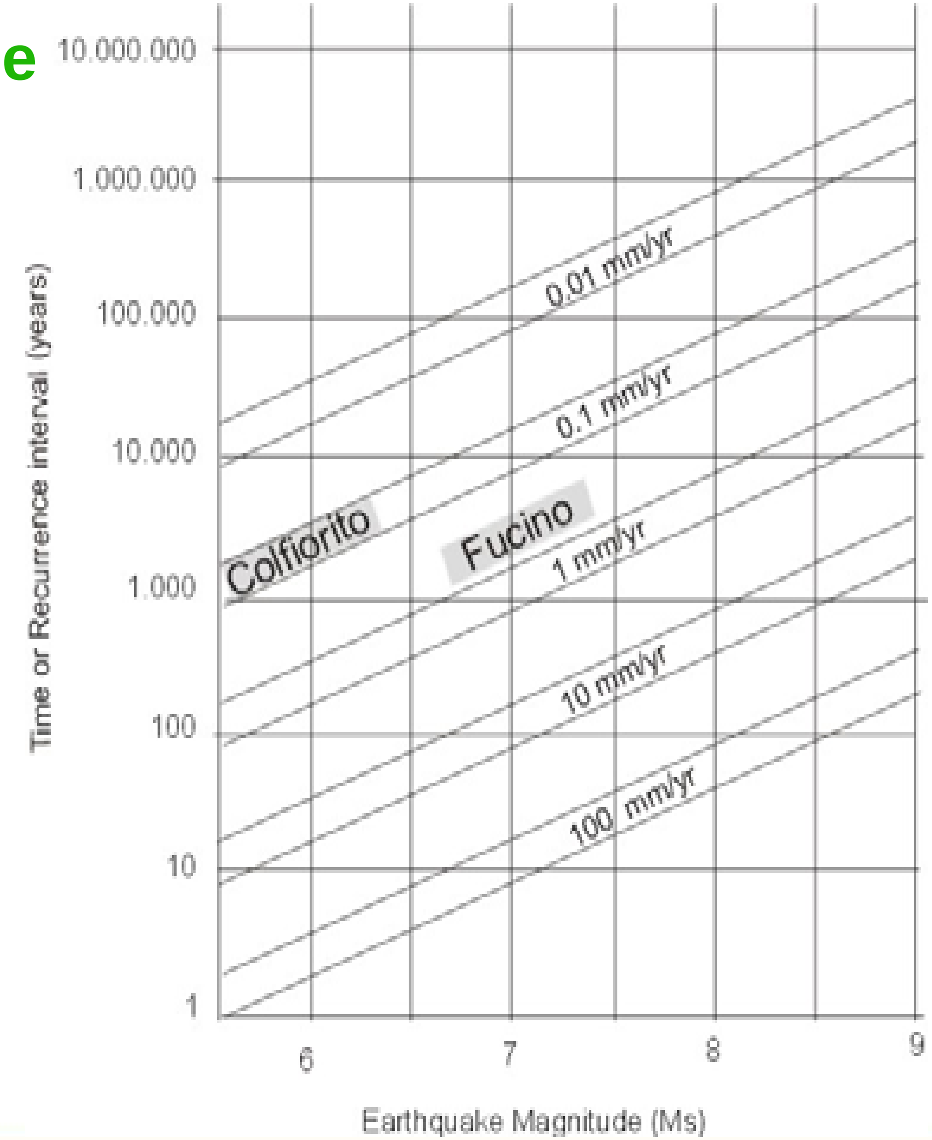

Considerations

The siting is the process of selecting a suitable location for any type of facilities, based on the assessment of the design parameters, in order to protect them from environmental hazards.
The process becomes more relevant and sophisticated with the increasing complexity of the facility.

The NPP’s siting criteria could be applied to high risk industrial plants, considering the risk level of such plants and related cost-benefit analysis.

It is an highly cost approach but it can be helpfully for Disasters Early Warning Systems and the benefit is high in the case an important event occur during the plant lifetime.