# Seismic Hazard Assessment

## Part 1: Earthquake Hazards and Seismic Hazard Analysis

**Dr. Fawad A. Najam**

Department of Structural Engineering
NUST Institute of Civil Engineering (NICE)
National University of Sciences and Technology (NUST)
H-12 Islamabad, Pakistan
Cell: 92-334-5192533, Email: fawad@nice.nust.edu.pk

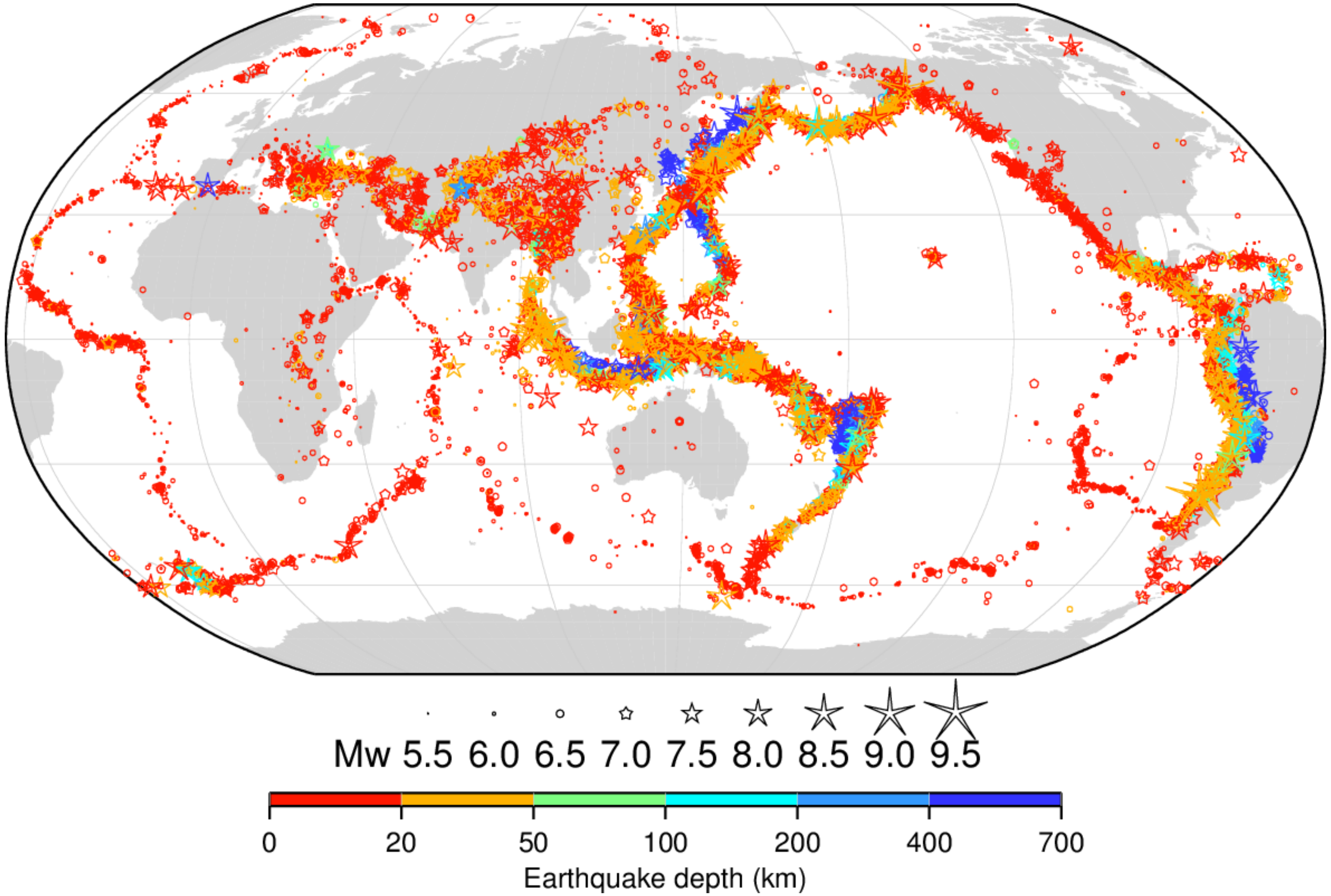
**Prof. Dr. Pennung Warnitchai**

Head, Department of Civil and Infrastructure Engineering
School of Engineering and Technology (SET)
Asian Institute of Technology (AIT)
Bangkok, Thailand

# Earthquake Hazards

# Earthquake Hazards

- 60% of all deaths by natural disasters are caused by Earthquakes [1]
- In 20$^{th}$ century, 17000 persons per year [2]




1. Shedlock and Tanner, 1999
2. Chen and Scawthorn, 2002

Figure Source: ISC

# Earthquake Hazards

- Ground shaking
- Ground displacement along faults: surface rupture
- Ground failures: soil liquefaction, landslide, mud slide, differential soil settlement, etc.
- Tsunami
- Floods from dam and levee failures
- Fires resulting from earthquakes

# Ground Shaking Hazard: Wenchuan Earthquake (2008), China

*Magnitude = 8.0*

# Ground Shaking Hazard: Kashmir Earthquake (2005), Balakot, Pakistan (*Magnitude = 7.7*)

# Ground Shaking Hazard: Yogyakarta Earthquake (2006), Indonesia

# Surface Rupture Hazard: The 1999 Chi-Chi earthquake, Taiwan


The 1999 Chi-Chi earthquake, Shih-Kang Dam

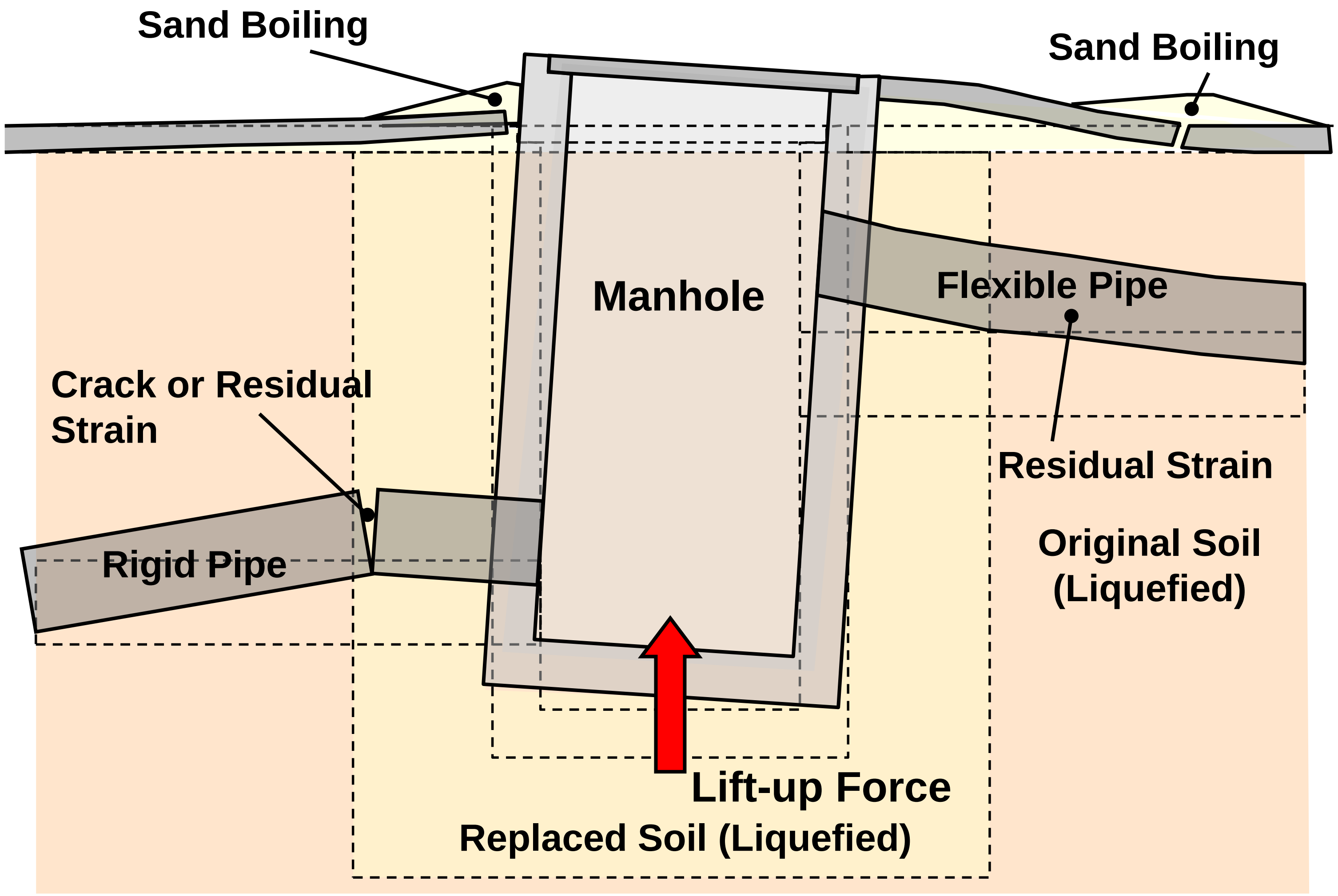
# Soil Liquefaction Hazard

## Loss of Bearing Capacity

A building in Dagupan, Philippines after the 1990 Luzon EQ

Overturned building in Adpazari, Turkey in the 1999 Kocaeli EQ

# Damage to Sewers




Tokachi-oki EQ, Hokkaido (2003)

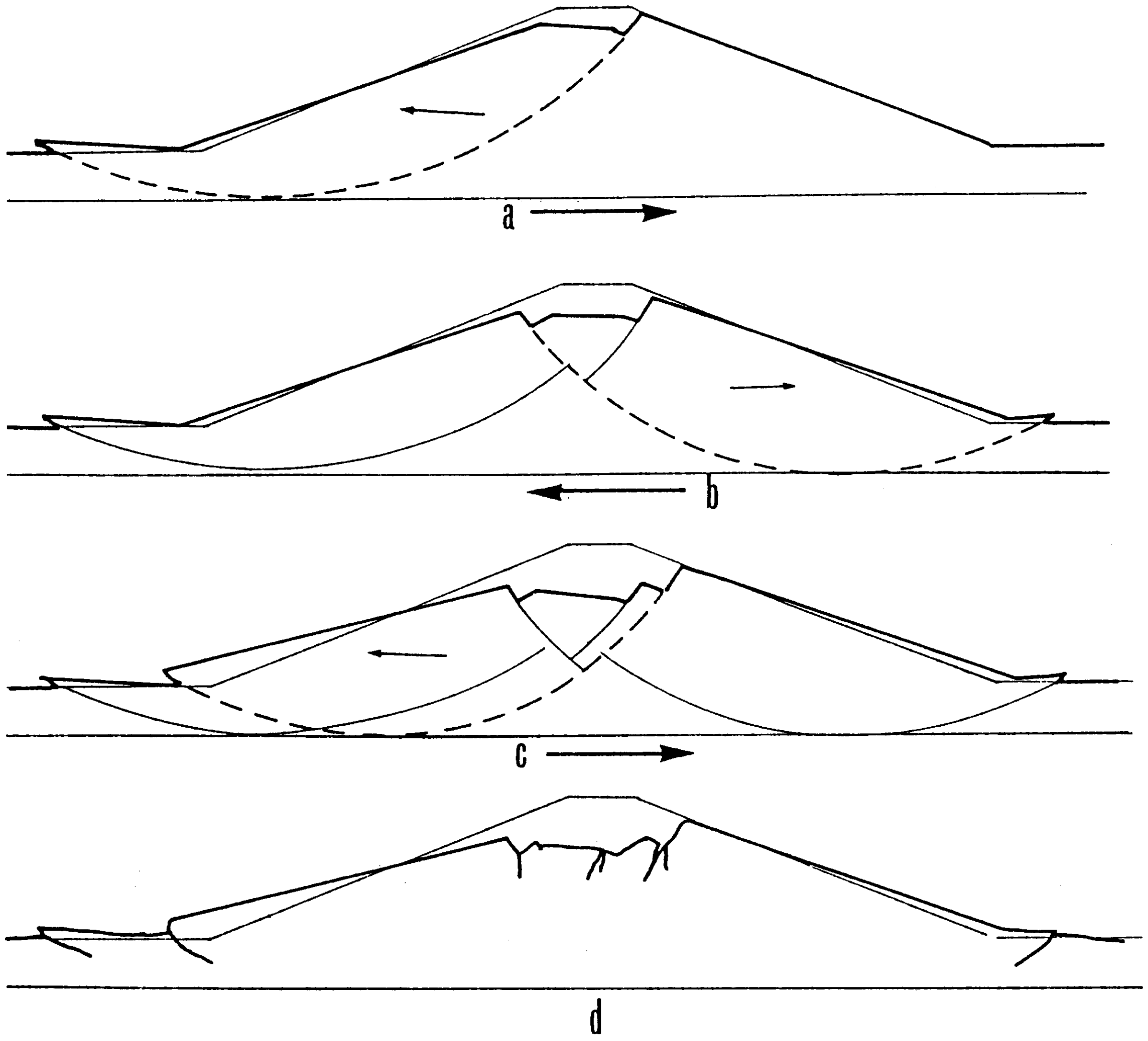
# Underground Pipe Failure in Baguio, Philippines

*(Luzon Earthquake, 1990)*

# Earthquake-induced Landslide in Wenchuan County, China

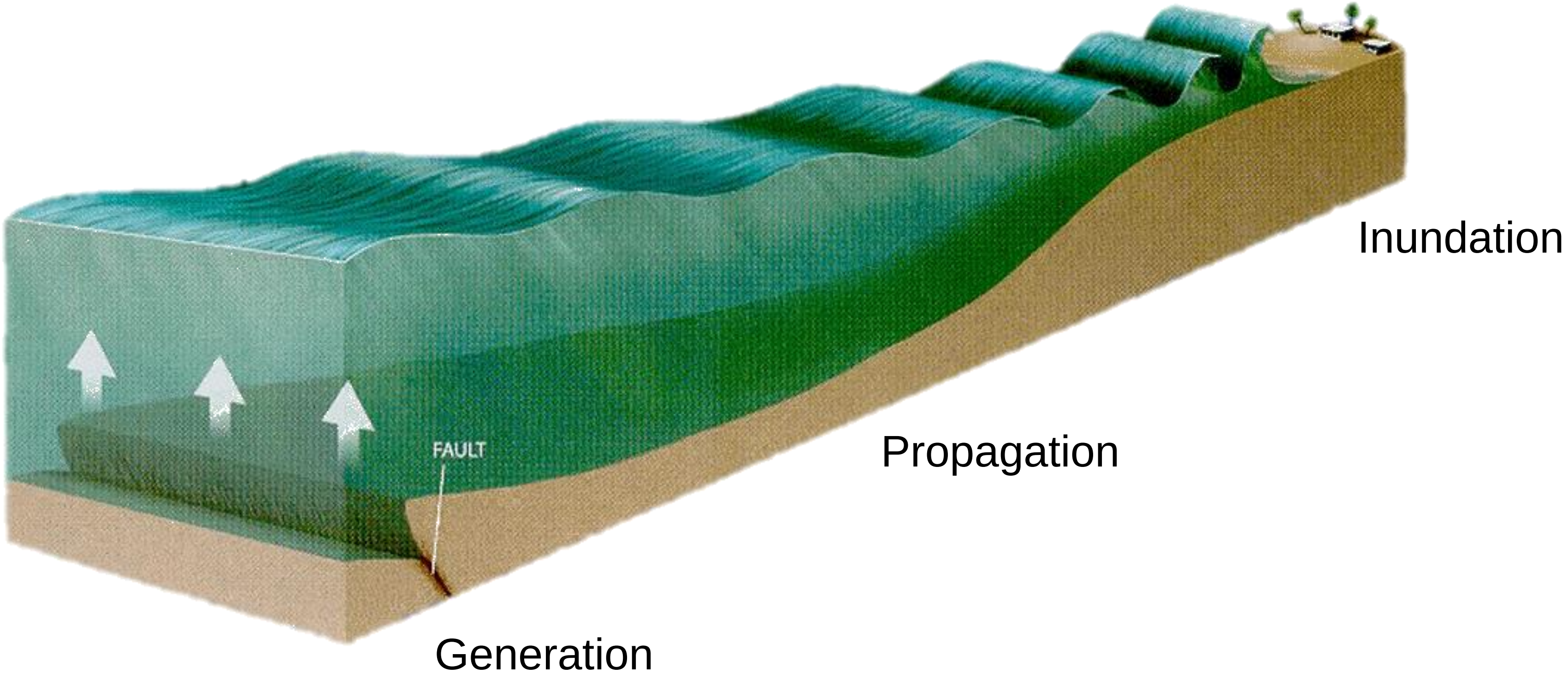
*(Wenchuan Earthquake, 2008)*

# Dynamic Stability of Embankment



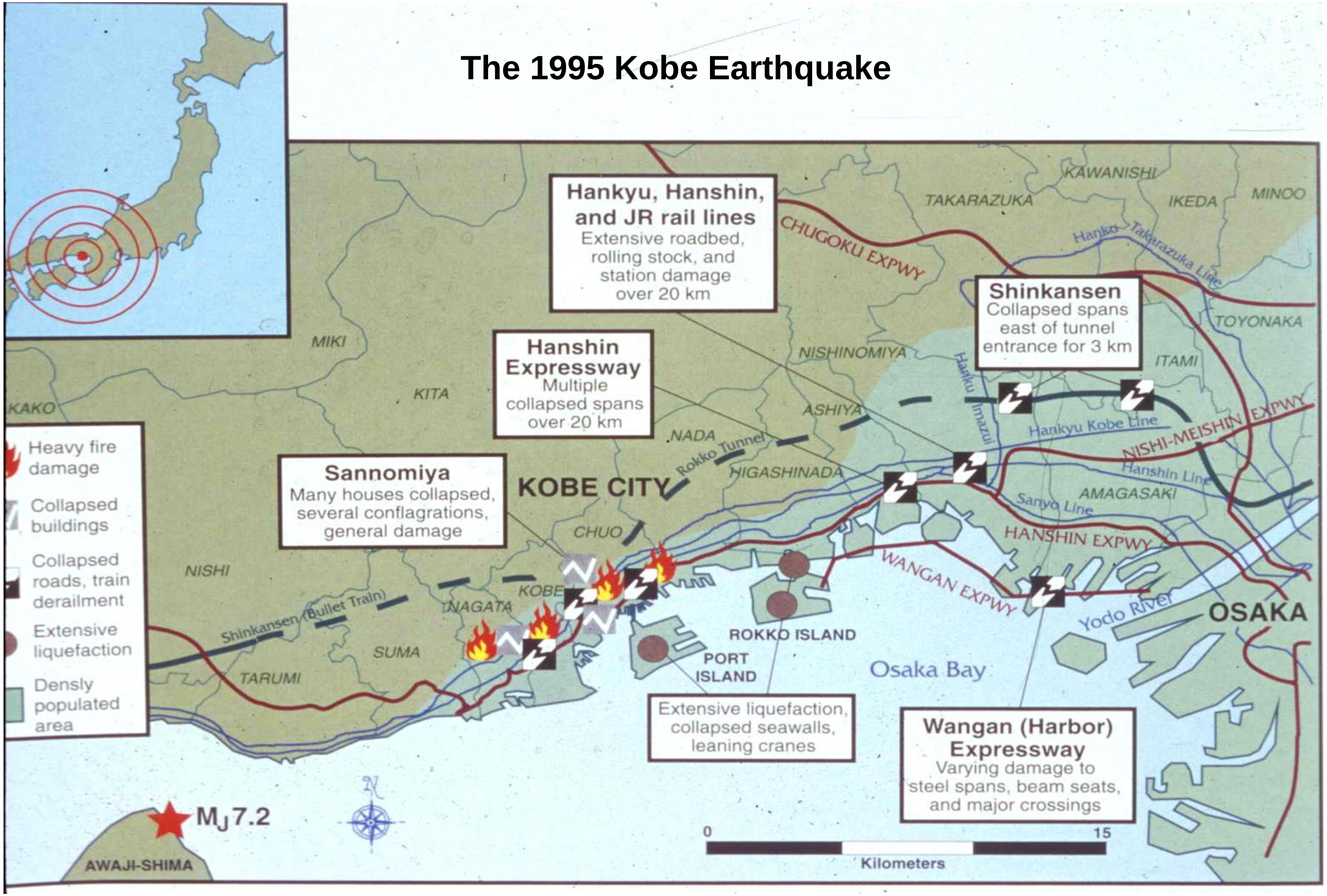
# Bhuj earthquake 2001 Irrigation Dams

# Tsunami generated by an Earthquake




Khao Lak, Phang-Nga
Maximum Water Level

# The 1995 Kobe Earthquake



# Fires resulting from the Earthquake (Kobe EQ, 1995)

# Fires resulting from the Earthquake (Kobe EQ, 1995)

# Basic Questions

- Where will future earthquakes occur?
- What will be their size?
- What will be their frequency of occurrence?
- What will be the ground shaking intensity at the site produced by earthquakes of different size, focal depth, and epicentral location?
- How will the ground motion be influenced by local soil conditions and geology?
- What will be the earthquake hazards (landslide, liquefaction, etc.) produced at the site?
- How about the susceptibility of buildings and structures to damage from the ground shaking and ground failures?

Lack of Resources for Communities

Population

Natural or Man-made Phenomena

**Inappropriate Built Environment**

Urbanization and Un-planned development

# Disaster = Hazard . Vulnerability . Exposure

(Hazard . Vulnerability = **Risk**)

To reduce risk of disaster and increase safety,
we need to estimate hazard properly,
and Reduce **Vulnerability**

# Seismic Hazard Assessment

## Seismic Hazard Assessment

**SEISMIC HAZARD × SEISMIC VULNERABILITY = SEISMIC RISK**

- In principle, **Seismic Hazard Assessment (SHA)** can address any natural hazard associated with earthquakes, including ground shaking, fault rupture, landslide, liquefaction, or tsunami.

- However, most interest is in the estimation of **ground-shaking hazard**, since it causes the largest economic losses in most earthquakes.

- Moreover, of all the seismic hazards, **ground motion is the predominant cause of damage from earthquakes**; building collapses, dam failures, landslides, and liquefactions are all the direct result of ground motion.

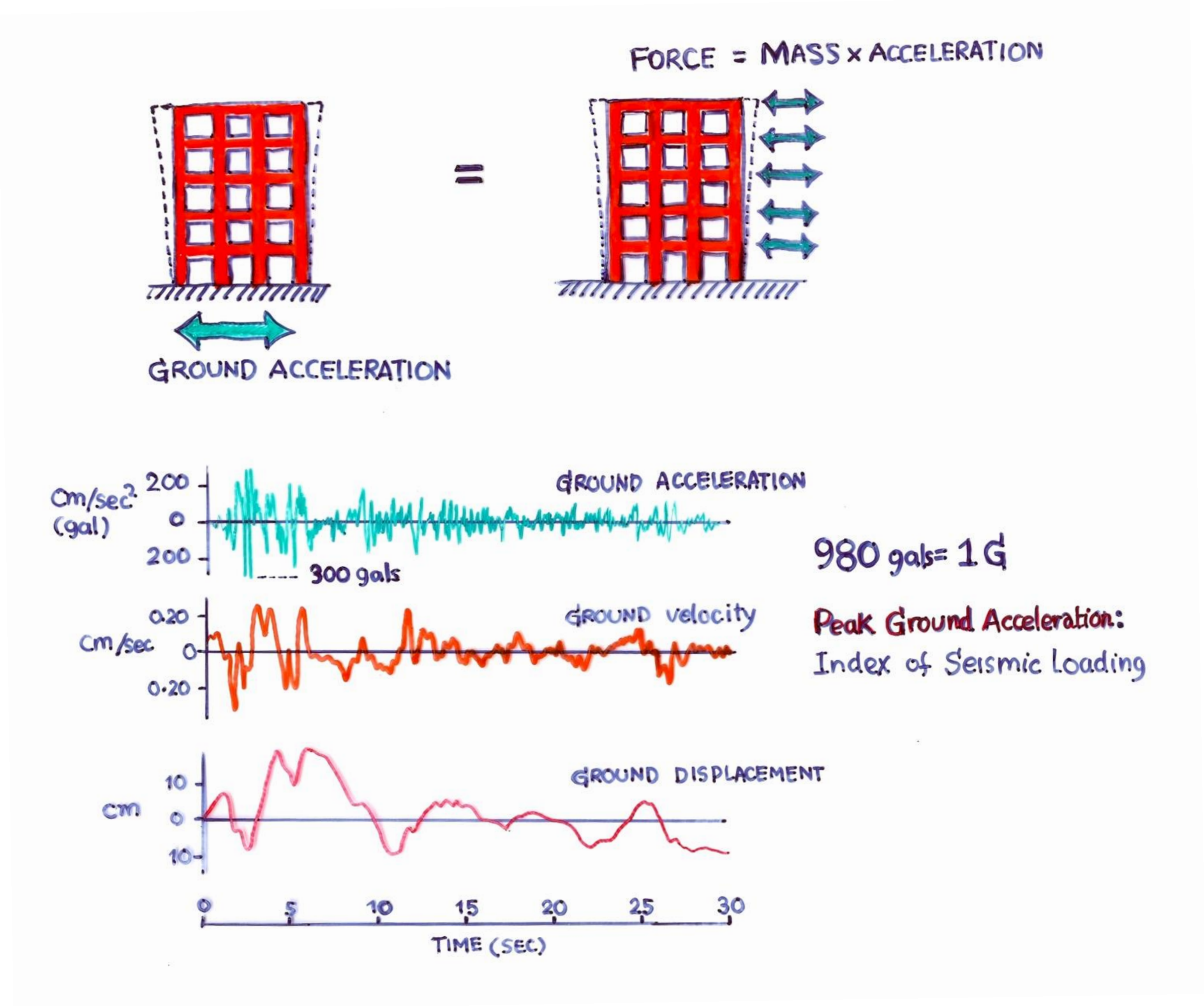
- *The Chapter, therefore, is restricted to the estimation of the **earthquake ground motion hazard***

# Ground Motion Parameters

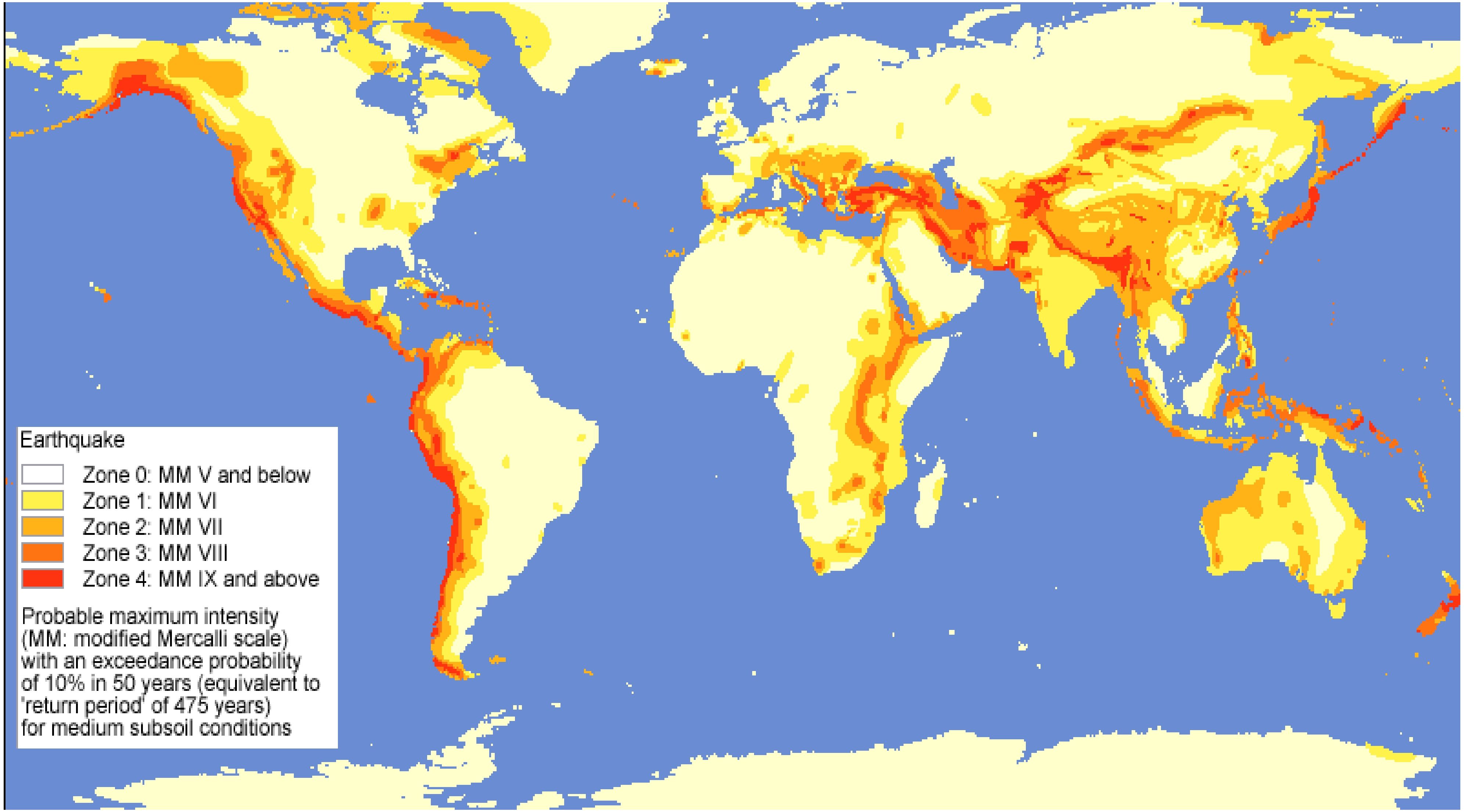
- There are many different ground motion parameters—displacement, velocity, acceleration, or MMI.

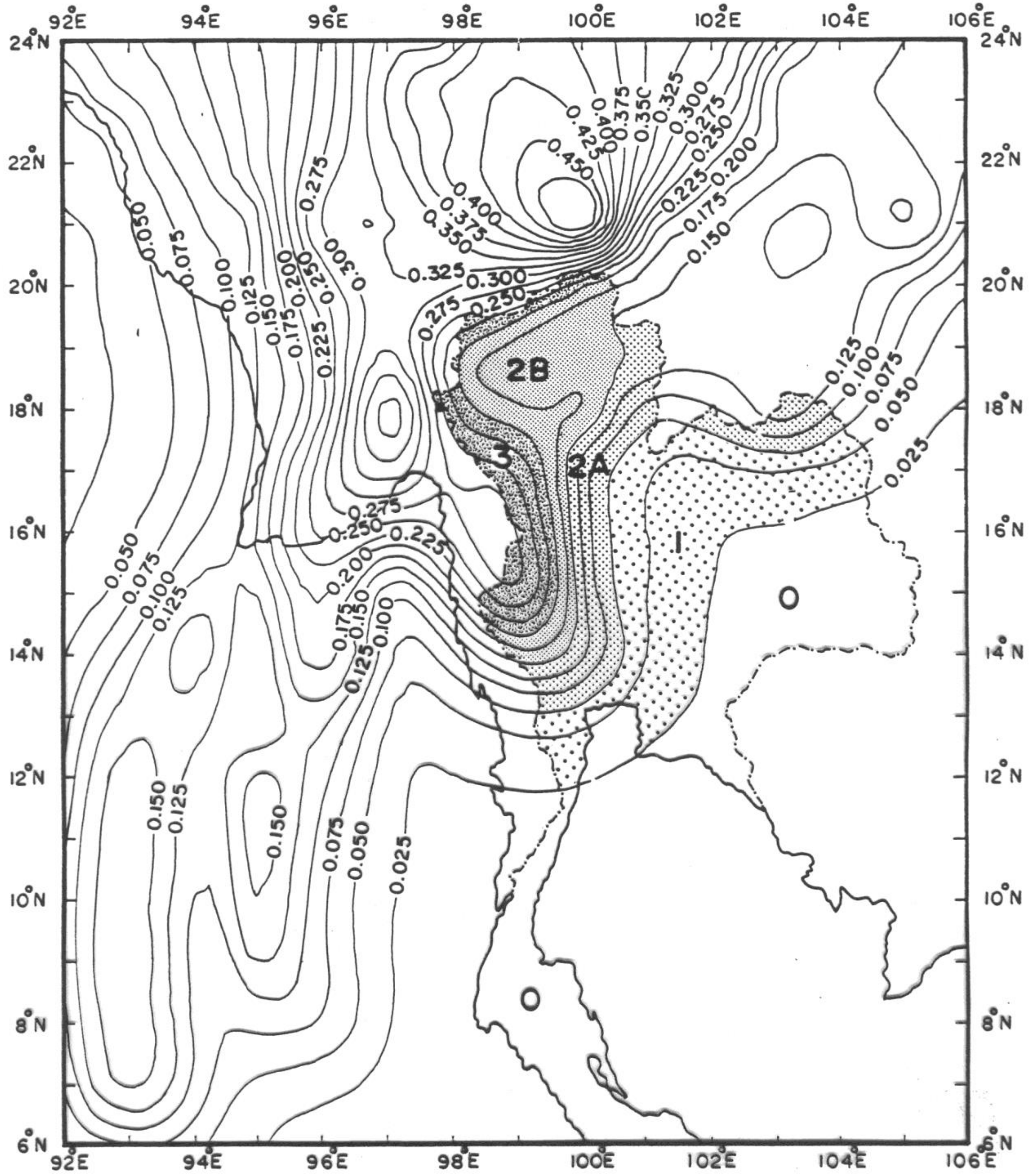
- Usually Peak **Ground Acceleration (PGA)** is considered to be the preferred ground motion parameter.

- **Seismic Hazard = Ground-shaking Hazard = the probability of occurrence of potentially destructive seismic ground shaking at a given site within a given time interval.**


FORCE = MASS x ACCELERATION
=
GROUND ACCELERATION
cm/sec²
(gal)
200
0
200
300 gals
GROUND ACCELERATION
0.20
cm/sec
0
0.20
GROUND velocity
10
cm
0
10
GROUND DISPLACEMENT
0
5
10
15
20
25
30
TIME (SEC)
980 gals= 1 G
Peak Ground Acceleration:
Index of Seismic Loading

# Global Seismic Hazard Map






# Seismic Hazard Map of Thailand

This map shows contours of PGA (in unit of *g* ) with 10% probability of exceedance in a 50-year exposure period.

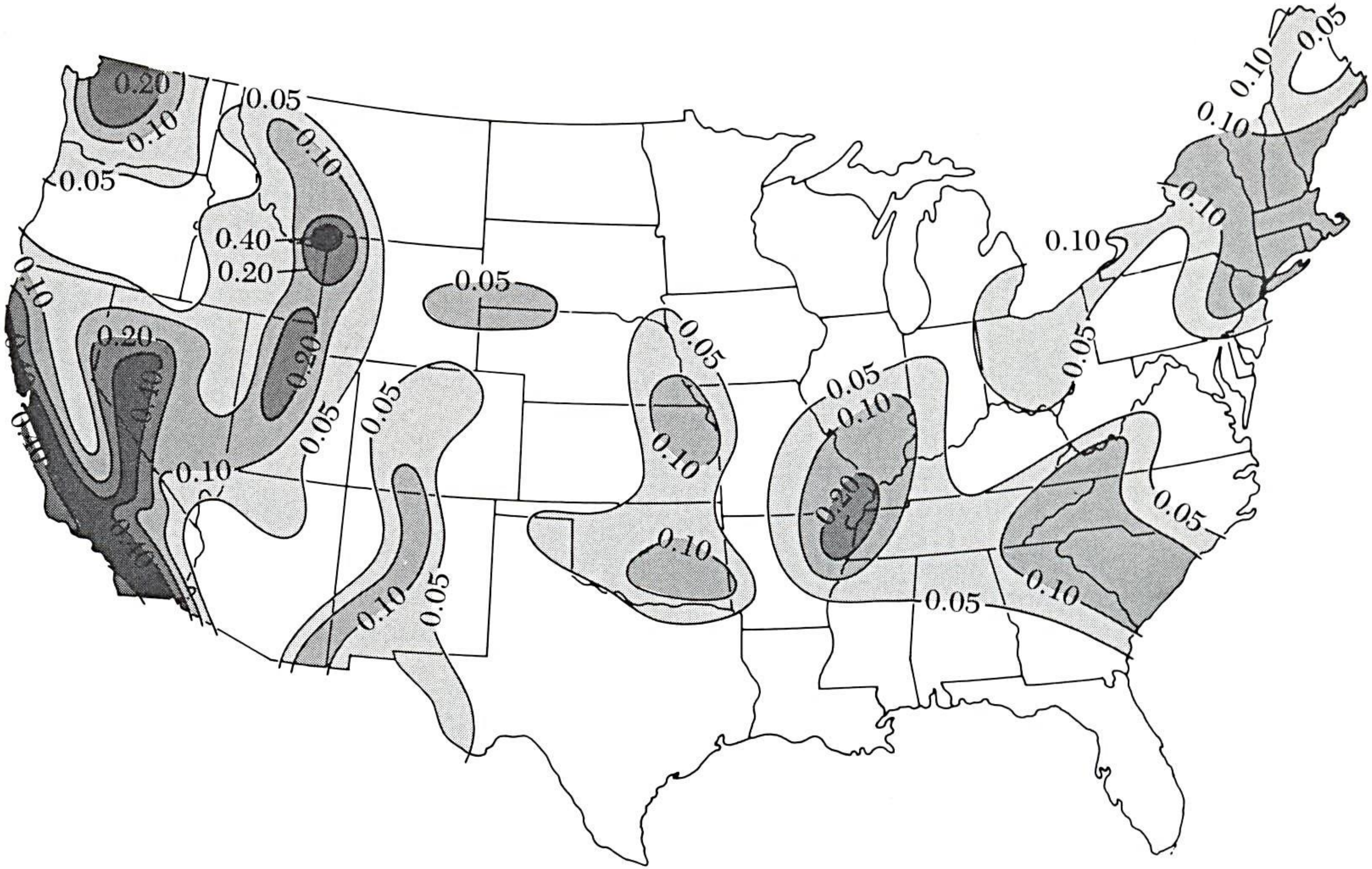



FIGURE 1
A new seismic risk map for the United States, prepared for the Applied Technology Council in 1976–77. The contours indicate effective peak, or maximum, acceleration levels (values are in decimal fractions of gravity) that might be expected (with odds of only 1 in 10) to be exceeded during a 50-year period.

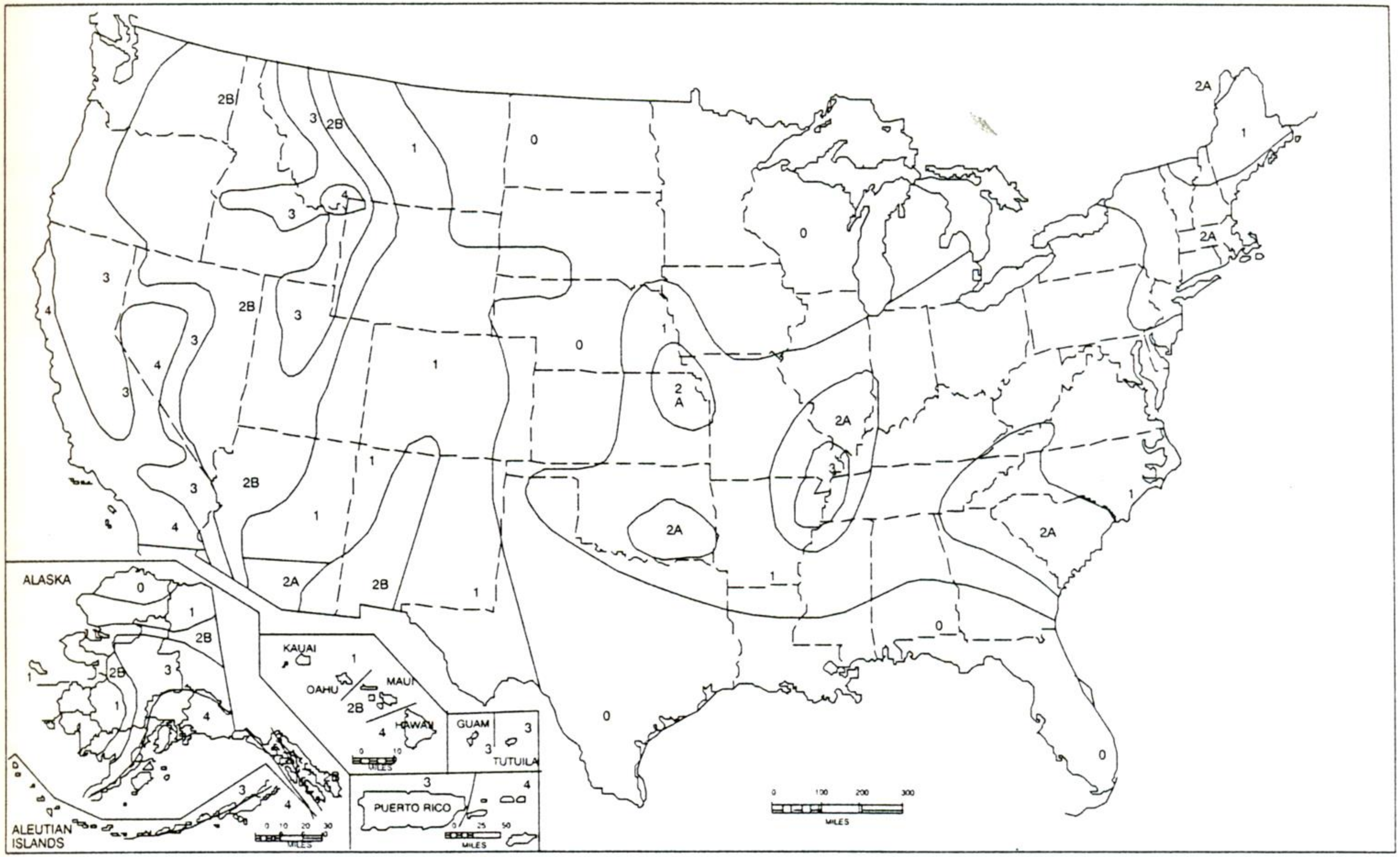
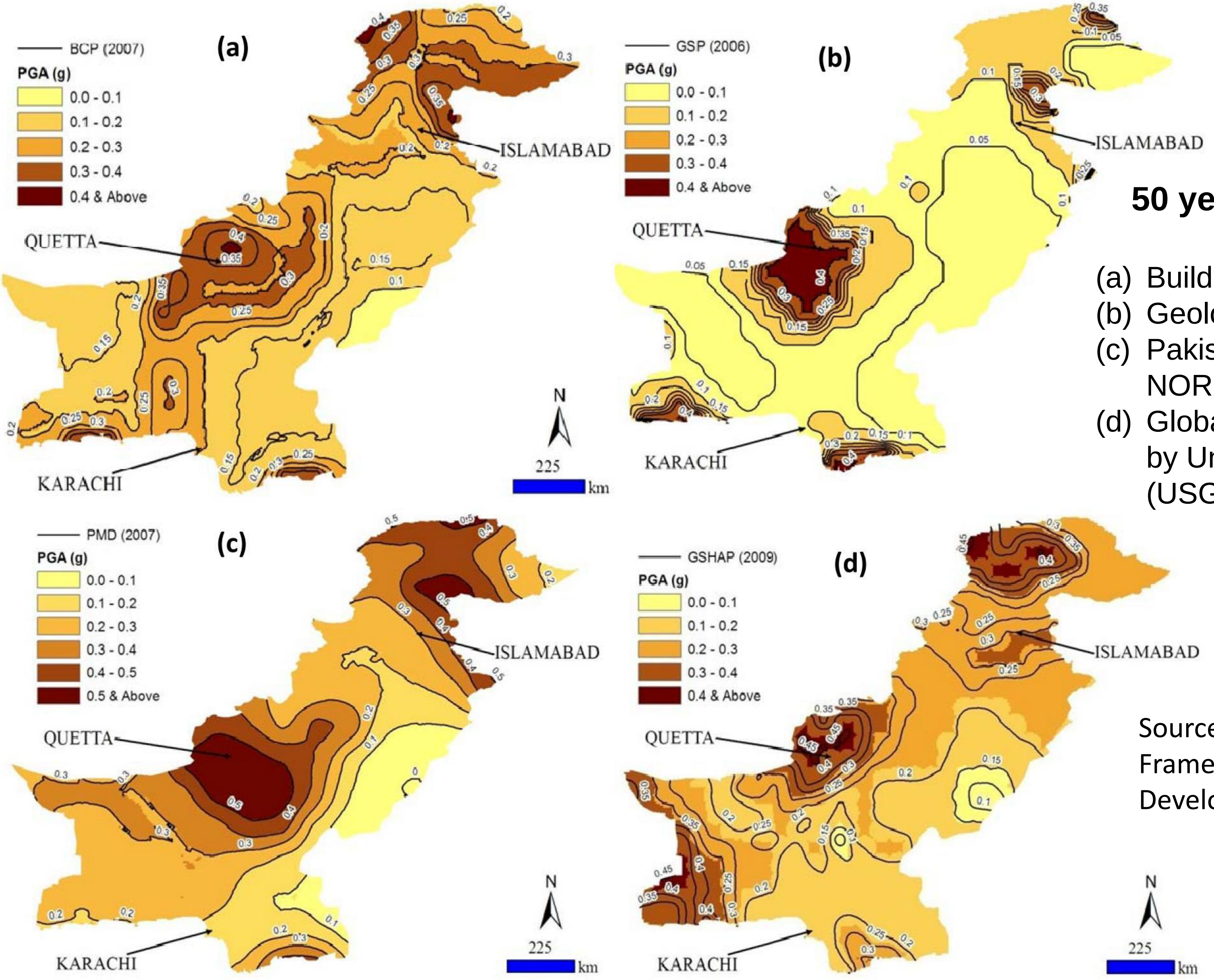


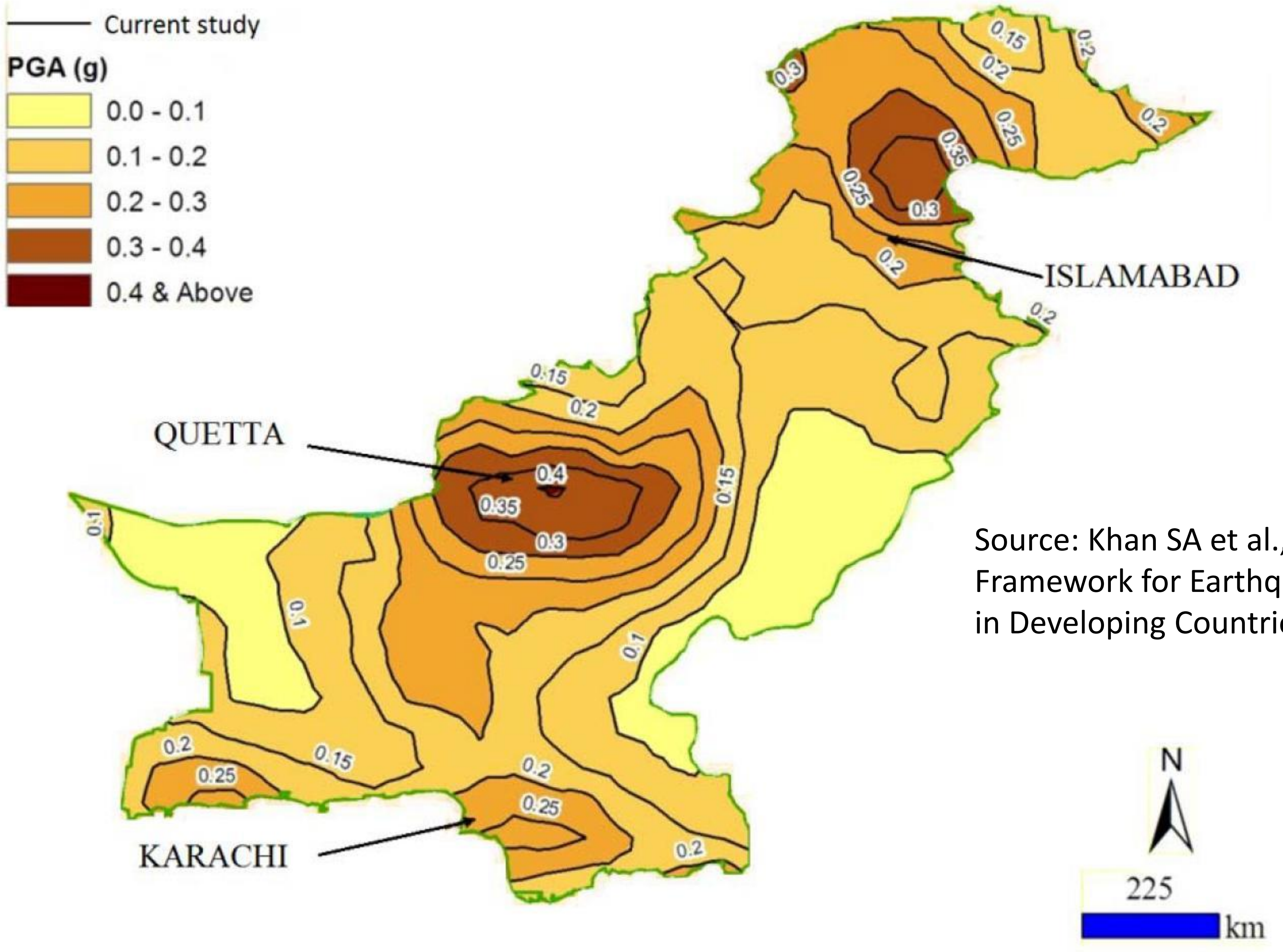

**FIGURE 16-2—SEISMIC ZONE MAP OF THE UNITED STATES**
**For areas outside of the United States, see Appendix Chapter 16.**




**50 year with 10% PE** seismic hazard map by

(a) Building Code of Pakistan (BCP, 2007),
(b) Geological Survey of Pakistan (GSP, 2006)
(c) Pakistan Meteorological Department (PMD-NORSAR, 2007) and
(d) Global Seismic Hazard Program (GSHAP) by United States Geological Survey (USGS, 2008)

Source: Khan SA et al., (2012). A New Framework for Earthquake Risk Assessment in Developing Countries




Source: Khan SA et al., (2012). A New Framework for Earthquake Risk Assessment in Developing Countries

# Seismic Hazard Assessment

- Seismic Hazard Analysis (SHA) has been widely used by engineers, regulators, and planners to mitigate earthquake losses:

  - ✓ **Specifying seismic design levels for individual structures and building codes**
  - ✓ **Evaluating the seismic safety of existing facilities**
  - ✓ **Planning for societal and economic emergencies (emergency preparedness)**
  - ✓ **Setting priorities for the mitigation of seismic risk**
  - ✓ **Insurance analysis**

# Probabilistic vs. Deterministic

- **DSHA** considers the effect at a site of either a single scenario earthquake, or a relatively small number of individual earthquakes. Challenge→ The selection of a representative earthquake on which the hazard assessment would be based.
- **PSHA** quantifies the hazard at a site from all earthquakes of all possible magnitudes, at all significant distances from the site of interest, as a probability by taking into account their frequency of occurrence.

- Deterministic earthquake scenarios, therefore, are a subset of the probabilistic methodology.

# Thank you for your attention