Seismic Hazard Analysis (SHA)

by

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Basic Definitions

F: Focus or hypocentre

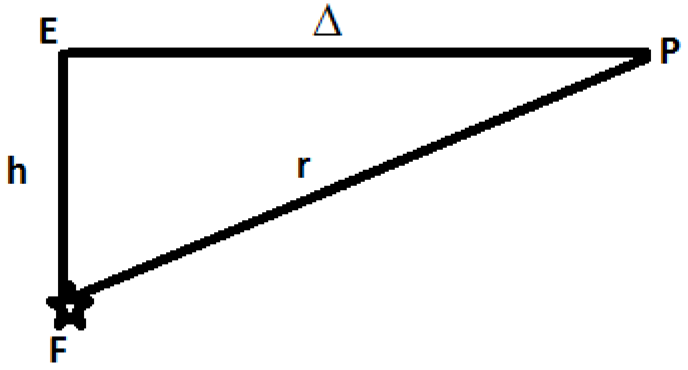
E: Epicentre

P: Point of Interest

h: Focal or hypocentral depth

r: Focal or hypocentral distance

Δ: Epicentral distance



Quantification of Earthquake

* Effects: Macroseismic Intensity (a measure of the effect of an earthquake upon natural objects, artificial structures, and human observers in a locality)
* Size: Magnitude (an absolute measure of earthquake size)
* Where: Location (world wide networks of seismograph, local microearthquake network)
* How Often: Seismic Hazard

Seismic Hazard

* The regional distribution of earthquakes (location of epicenters, magnitudes, focal depth, occurrence in years etc.) is often used for SHA.
* The study of the earthquake parameters is called seismic hazard

Seismic Hazard as probability statement

* Suggested requirements of an earthquake prediction are place(almost recognized for interplate and active faults) , magnitude and time
* We are successful in the first two (place and magnitude) upto some extent but not in time
* Thus we use fourth thing of probability statement

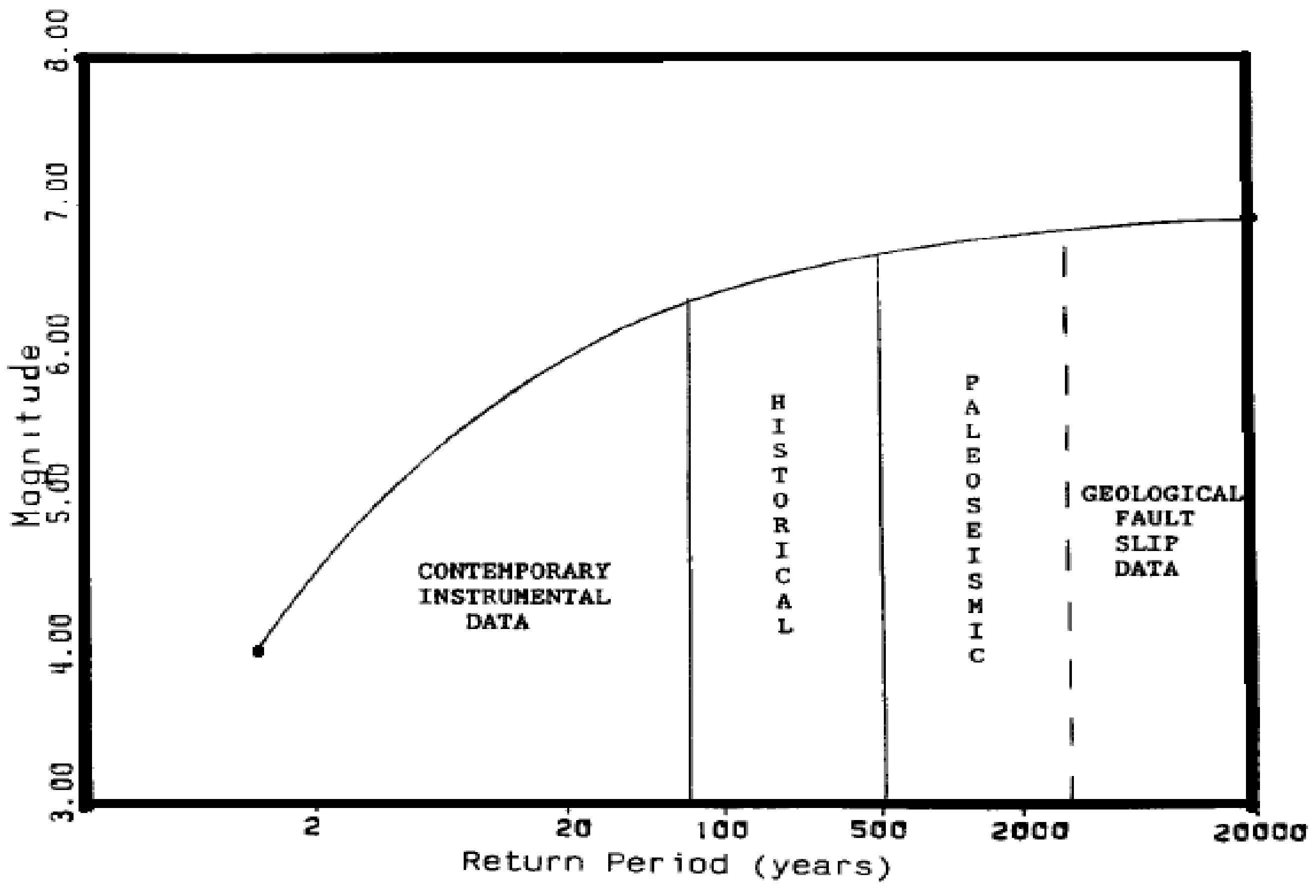
Definition of Seismic Hazard wrt Probability

* The probability of earthquake occurring
* Expected earthquake occurrence of magnitude can be calculated on the basis of probability and the expected magnitude occurrence are referred to seismic hazard

Seismic Hazard Analysis (SHA)

* To study the process of earthquake parameters is called SHA
* study of ground motion parameters (peak ground acceleration, peak ground velocity and peak ground displacement etc is called SHA.
* Also known as hazard mapping

Input to Seismic Hazard



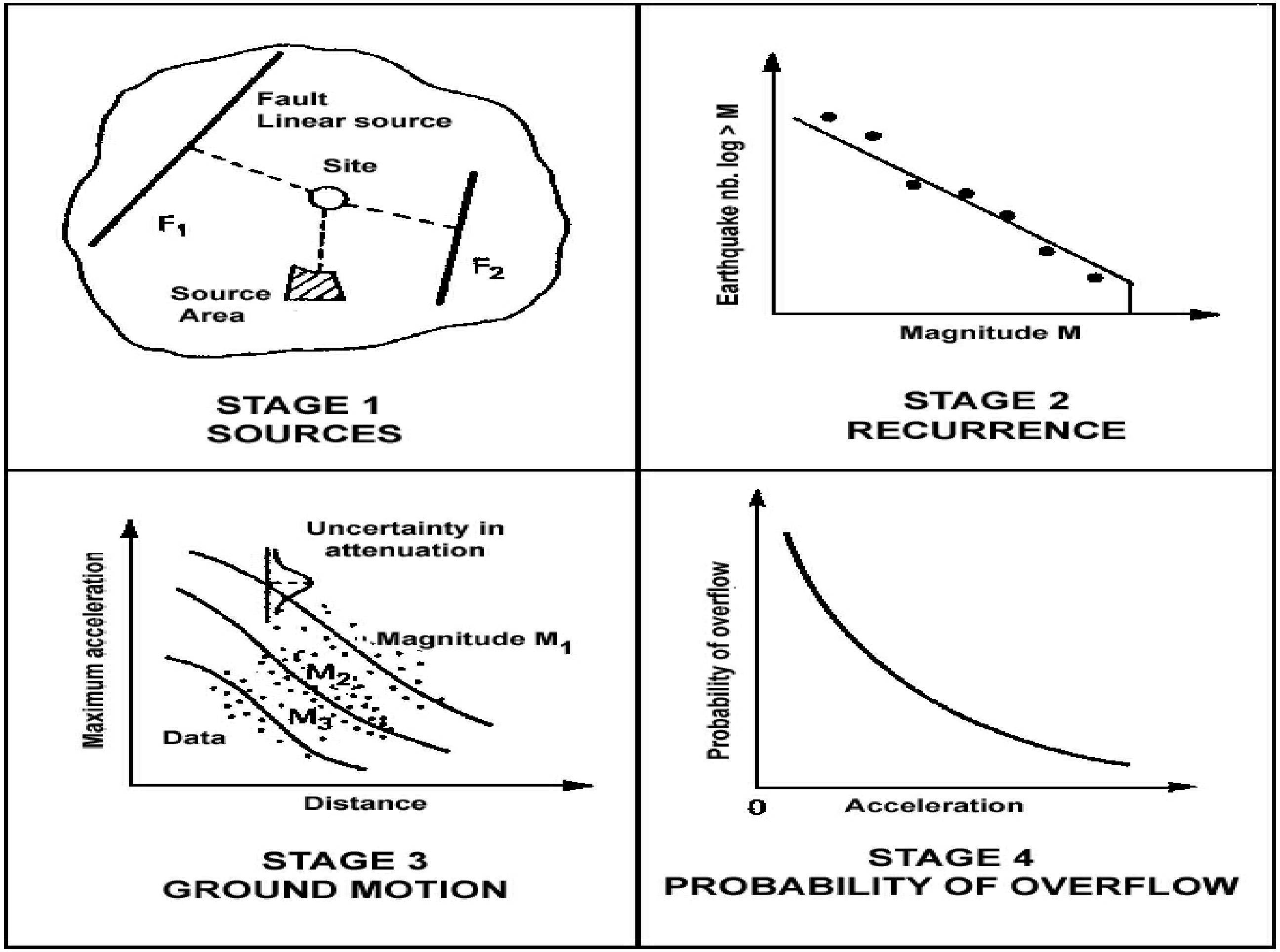
Desirable properties of Earthquake Catalogues (data input)

* Homogeneity
* Completeness
* Duration
* Source material
* Computer readable

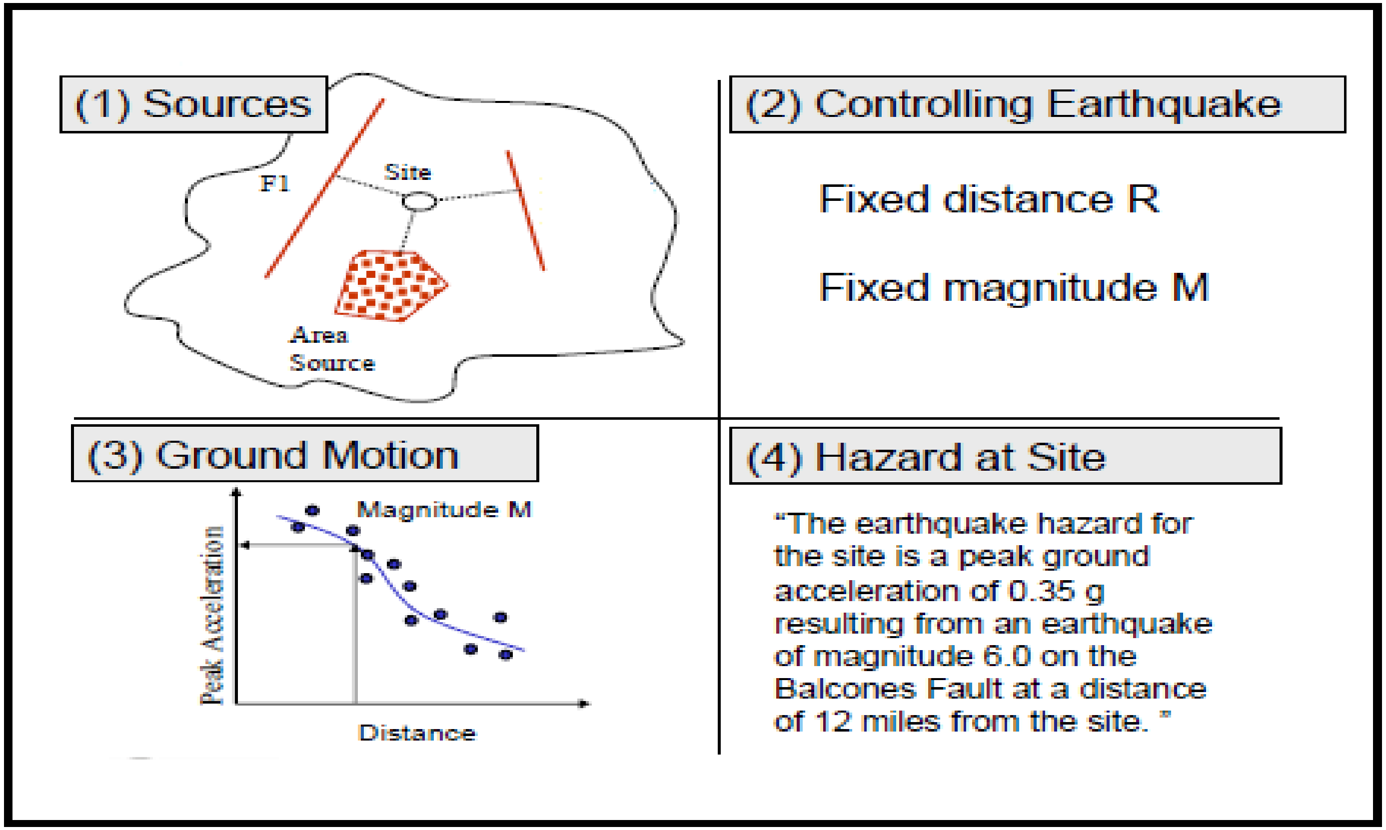
SHA Procedure (Deterministic and Probabilistic)

* Deterministic SHA: Taking single magnitude and distance of an earthquake to get Peak Ground Acceleration (PGA) is called deterministic hazard for a site.
* Understandable scenarios
* Uncertainty is not involved
* Results can be change by introducing new occurring earthquakes

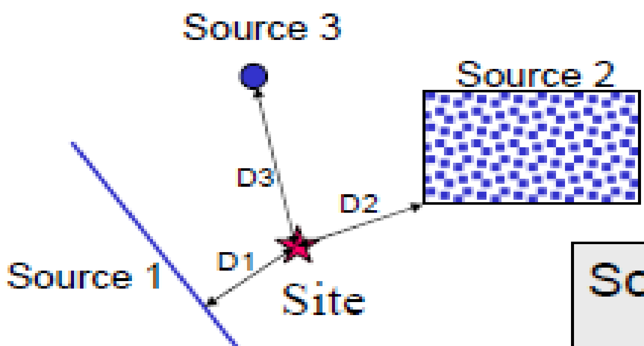
Deterministic SHA (Kramer)



Steps in Deterministic SHA (USGS)



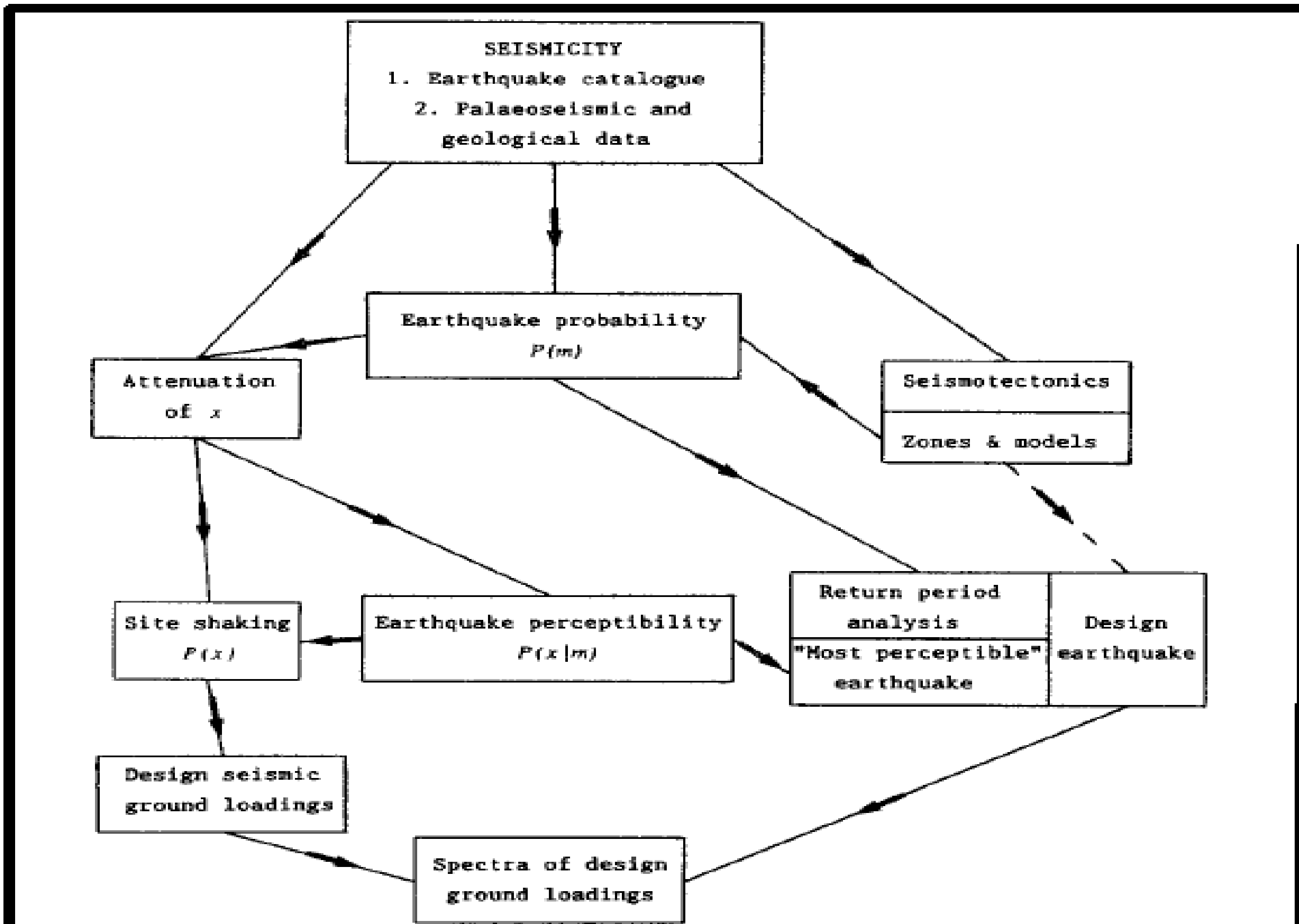
Example of Deterministic Analysis



Source	M	D (km)	PGA (g)
1	7.3	23.7	0.42
2	7.7	25.0	0.57
3	5.0	60.0	0.02

Maximum on source (M)
Closest distance (D)
From attenuation relationship (PGA)

Different contributing components to Probabilistic SHA



Probabilistic SHA

* Earthquake probability P(m): statistical distributions used to estimate P(m), given a earthquake catalogue in a region
* Other Path: seismotectonic evidence, zone a region into different earthquake groupings and then assess earthquake probabilities associated with each zone or grouping (Cornel method)

Poisson Distribution

* Commonly used distribution in SHA
* Its main assumptions are that the events are independent and the process is stationary
* If λ is the mean number of earthquakes per unit time, then n the number of events follows the Poisson distribution

  $F(n,\lambda t) = (\lambda t)^n / n \; e^{-} \lambda t$

General PSHA

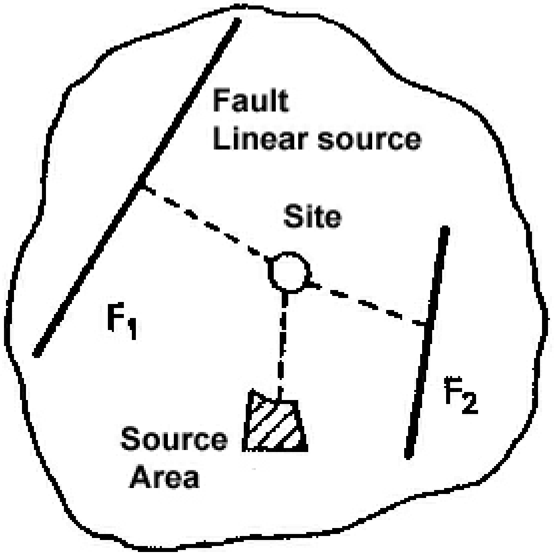
* 1) Historical Earthquake Occurrence(no need of fault knowledge and source dimension, Gridded)
* 2) Cornell Approach (fault based)
* Cornell approach assumes seismic sources as being points, lines or dipping planes. Seismic parameters such as seismic activity and the maximum probable magnitude are assigned to each source
* Both methods assume that the seismicity within the area or zone is uniform, that's each point within the area has the same probability of being the epicentre of future event.

Cornell method using seismogenic sources

* considers homogeneous seismotectonic sources (point, fault or zone) and then assesses earthquake probabilities associated with each zone
* This method consists of incorporating probabilistic characterizations of earthquake occurrence modelling, seismic-sources, magnitude-recurrence relations, and attenuation relations.

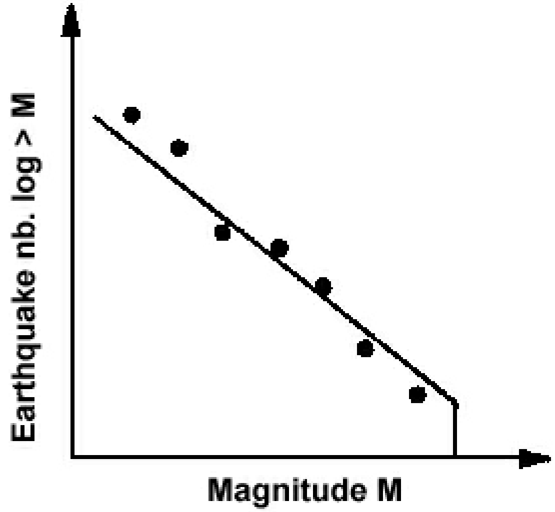
Step 1

* Definition of earthquake sources. Sources may vary from small faults to large seismotectonic zones. The source zones are determined by geoscientist from the combination of spatial-temporal seismicity, tectonic, geophysical, seismological data.



Step 2

* Prepare Earthquake catalogues. To determine the magnitude-frequency parameters and the maximum magnitude.
* Gutenberg-Richter law

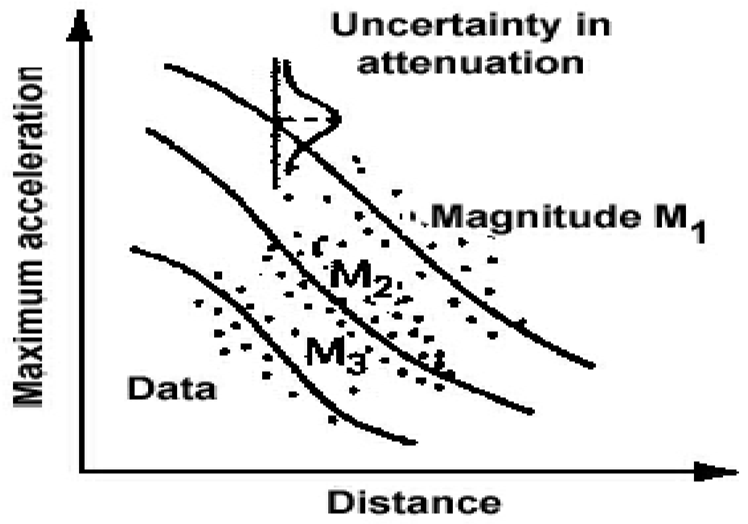


Gutenberg-Richter law of magnitudes

* Log N(m)= a-b.m
* N(m) is the number of events per year having magnitudes greater than m, and a and b are constants defined by the regression analysis
* This formula need knowledge of the complete earthquake catalogue above a threshold magnitude. It has theoretically unlimited magnitude and non-linearity is observed at low and high magnitudes due to incompleteness within a dataset at low magnitudes and the small number of occurrence of earthquakes with higher magnitudes.
* Small earthquakes have short recurrence period and the large earthquakes have much larger recurrence time.
* As small events occur often we have enough events to calculate an accurate recurrence time for them. The upper end of this formula do,t always accurately define a maximum earthquake.

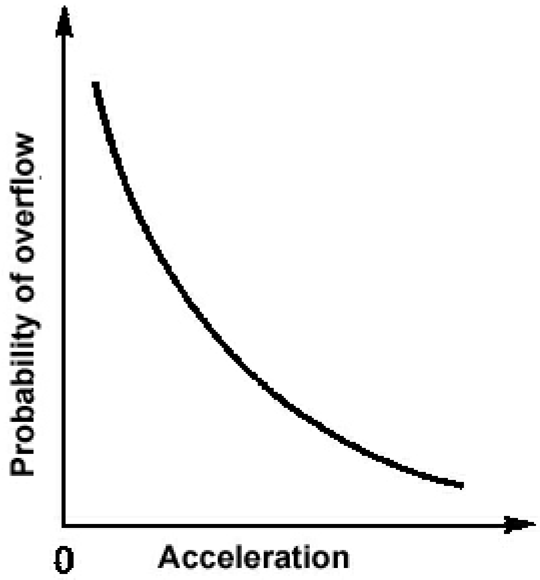
Step 3

* Estimation of earthquake effect. The evaluation of strong seismic ground motion: to relate a ground motion parameter (PGA) with seismological parameters (magnitude, distance etc.)



Step 4

* Determining the hazard at the site. The computation of seismic hazard and probability of occurrence of ground motion levels during a specified period of time using the integration of the above three steps over all possible magnitudes and earthquake locations.

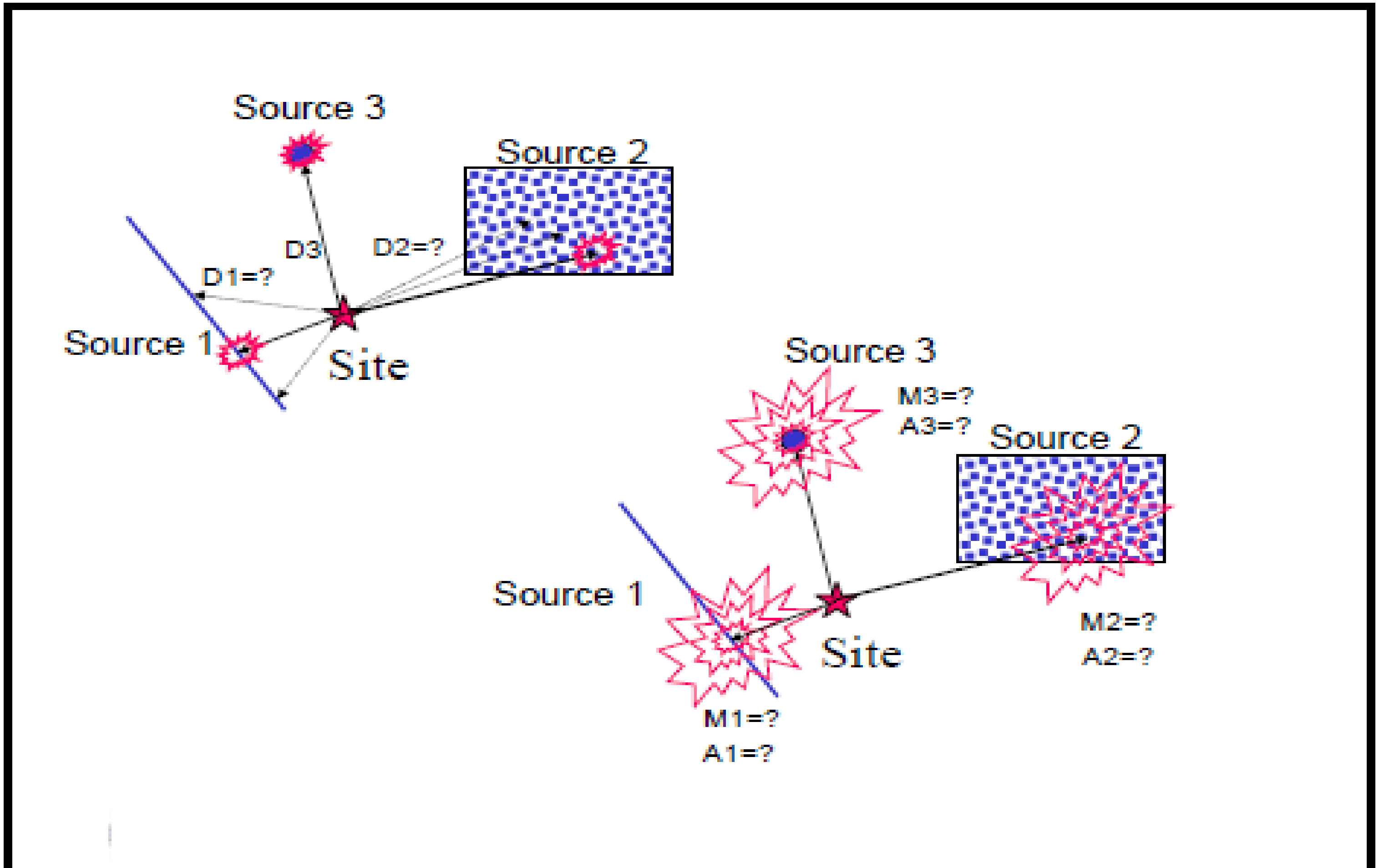


Uncertainty in PSHA

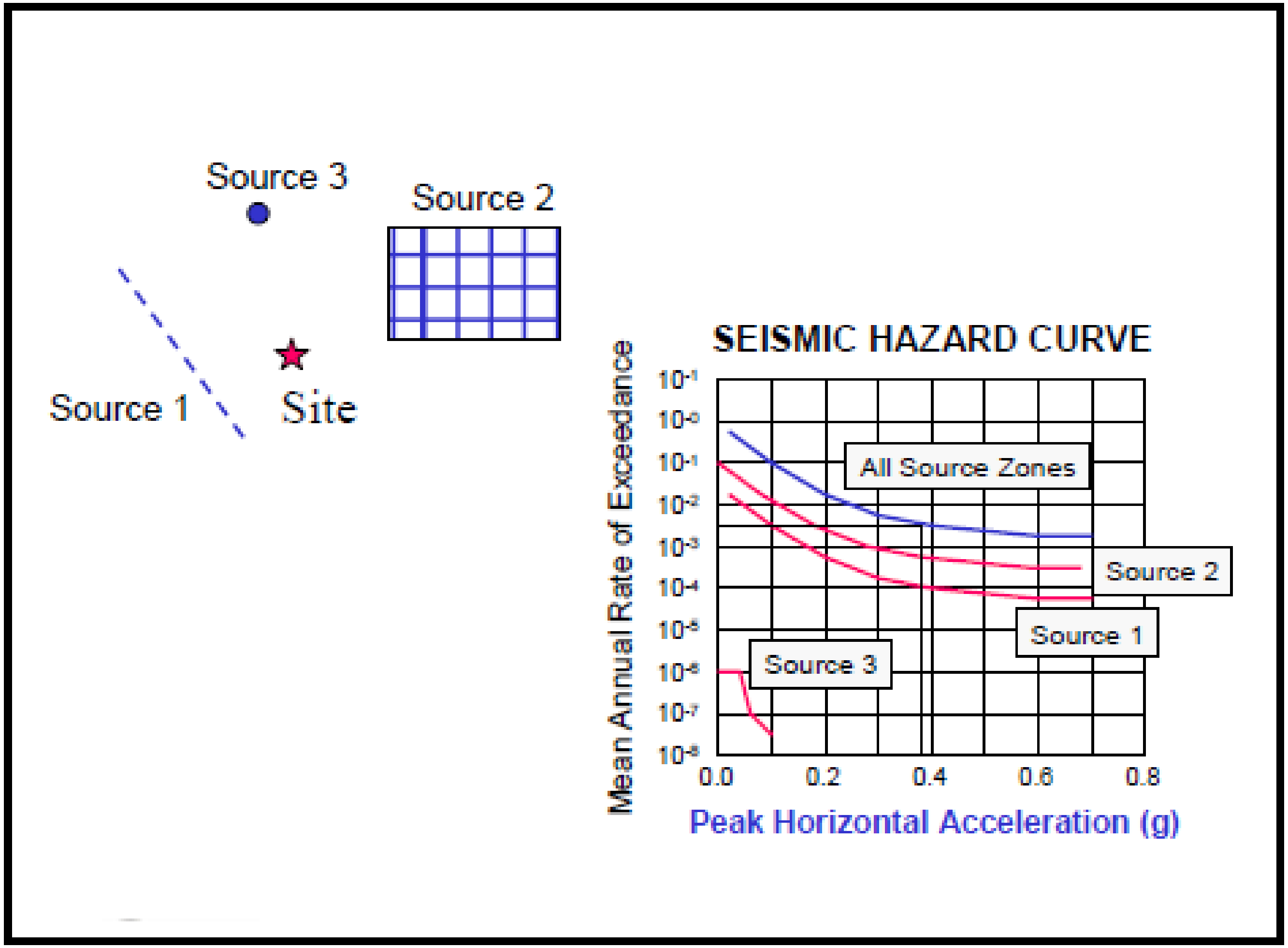
- PSHS includes wide range of information and uncertainties into a flexible framework
- Two major types of uncertainty in seismic hazard assessment
- aleatory (or stochastic) and epistemic (knowledge-based) uncertainty
- Epistemic uncertainty refers to uncertainty that arises due to incomplete knowledge of the earthquake process. Obtaining new data and refining the modelling can reduce the epistemic uncertainties

* The aleatory uncertainty is sometime refers to irreducible uncertainty.
* the aleatory variability may refers to the scatter in attenuation term (sigma)

Example of PSHA (USGS)



Results of PSHA (example)



Next Generation Attenuation (NGA) Models (Four Models)

* It was a five year program (2003-2008). It was coordinated by Pacific Earthquake Engineering Research Center . It was comprehensive multidisciplinary program including seismologists, geologists, engineers, researchers and users.
* Compile largest ground motion database worldwide
* New features (to created attenuation models for horizontal ground motions, Peak ground acceleration, velocity and displacement, spectral ordinate from period 1 to 10 sec, magnitude (8 and above), distance (0-200 km)

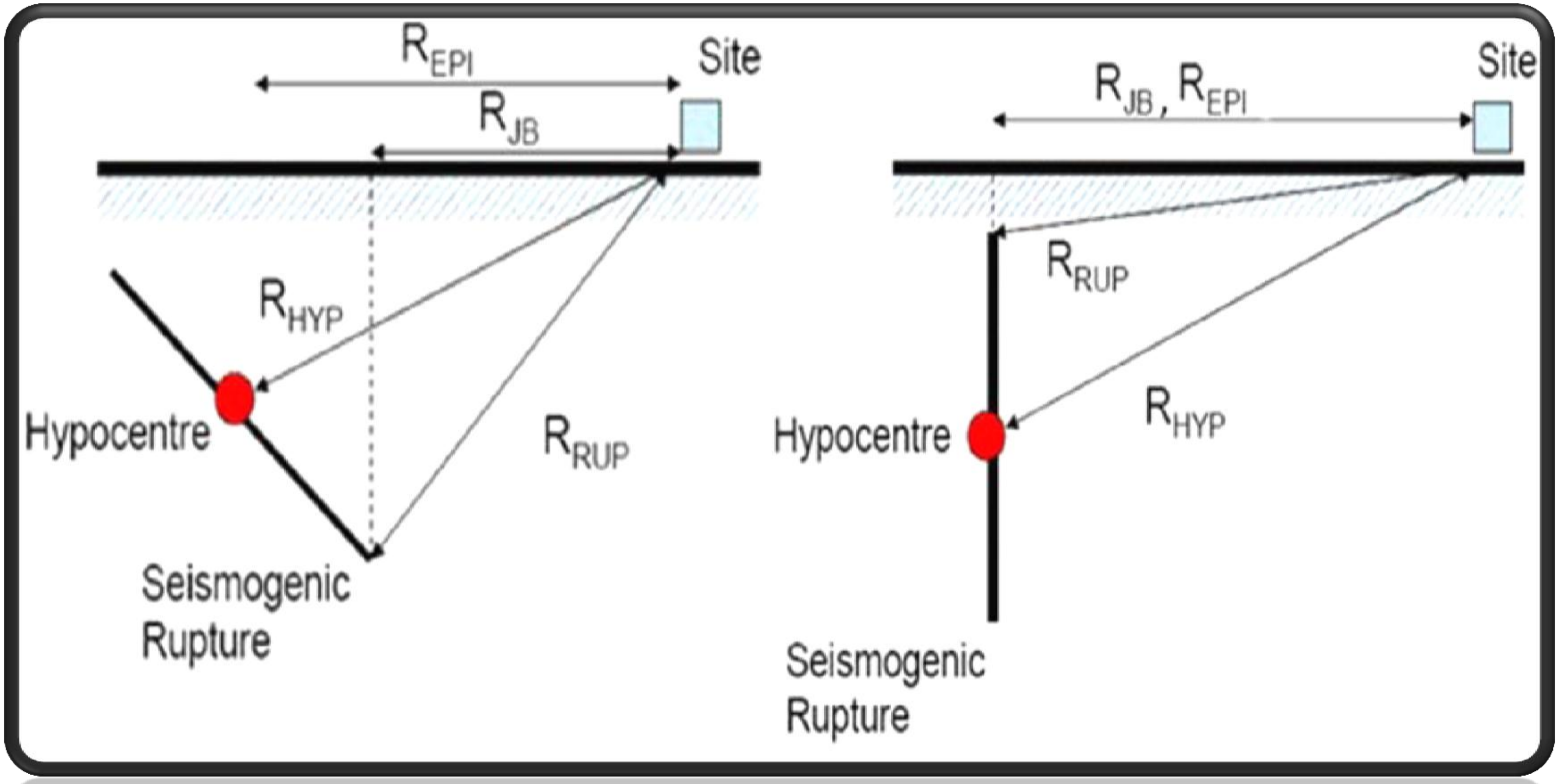
Four Models

* Abrahamson and Silva (2008)
* Boore and Atkinson (2008)
* Campbell and Bozorgnia (2008)
* Chiou and Youngs (2008)

NGA Parameters

* Magnitude scaling (moment magnitude)
* Source to site distance
* Local Site conditions
* Faulting style
* Variability

Source to Site Distances



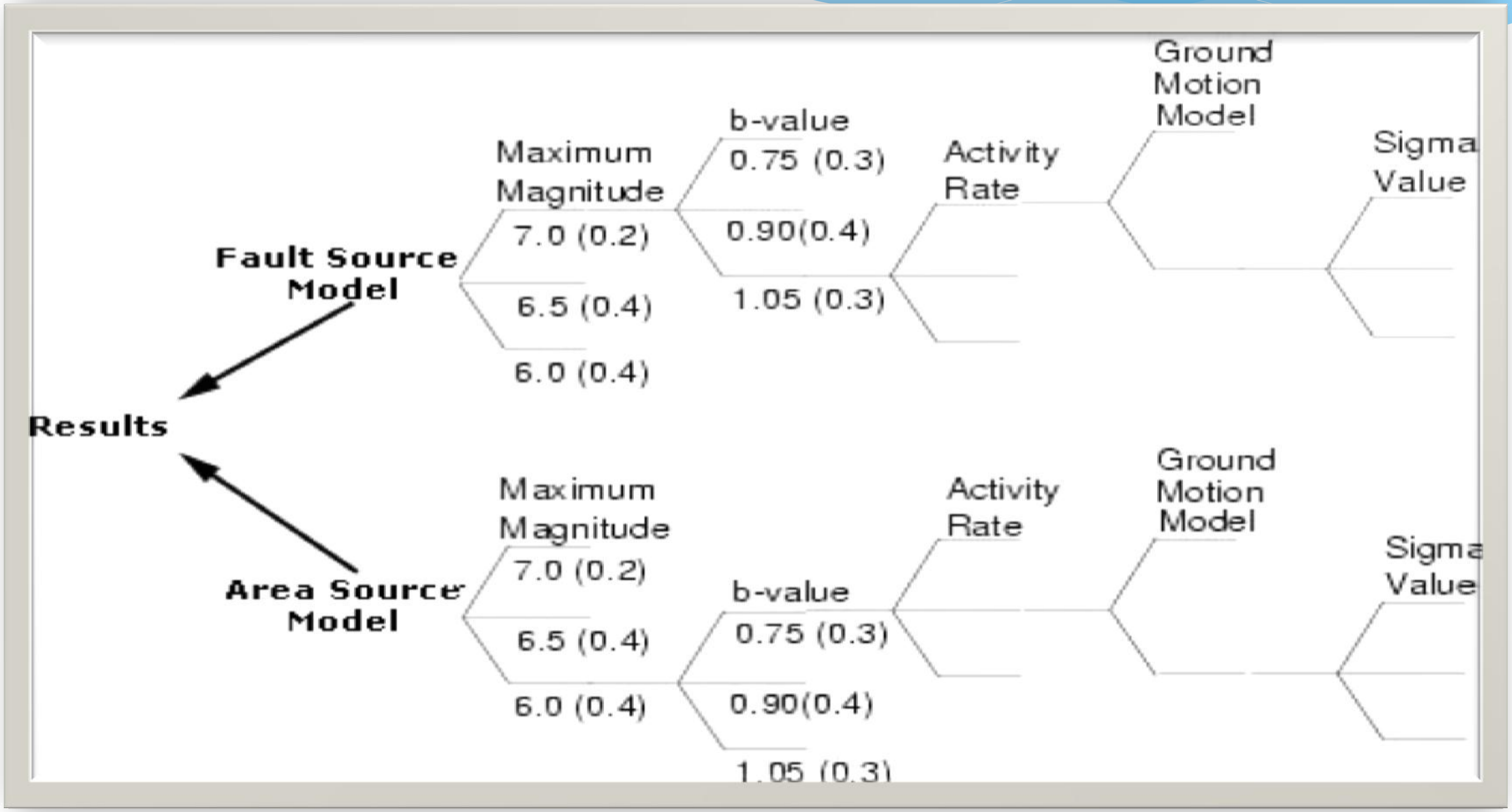
Local site condition

* Surface geology
* Near surface geology
* V_{s30}

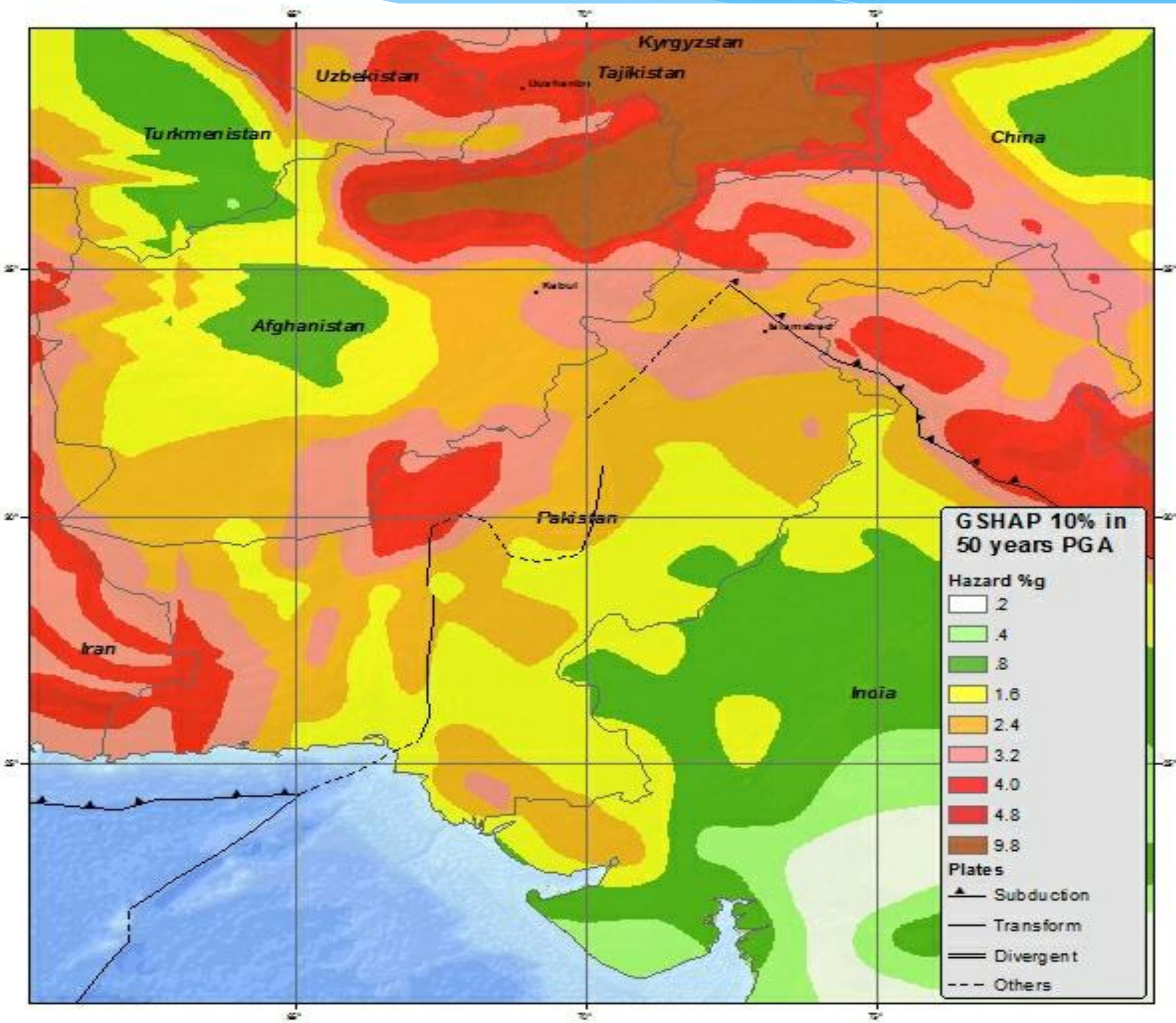
Faulting style and variability

* Strike slip fault
* Reverse fault
* Interevent variability (earthquake to earthquake)
* Intraevent variability (site to site)

Logic tree Methods



Pakistan SHA Map (USGS)



Thank you