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Seismic Hazard in Asia

4 - 8 December 2006

An effort Towards the Assessment of Earthquake Hazard in the Indian Subcontinent

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AN EFFORT TOWARDS THE ASSESSMENT OF EARTHQUAKE HAZARD IN THE INDIAN SUBCONTINENT

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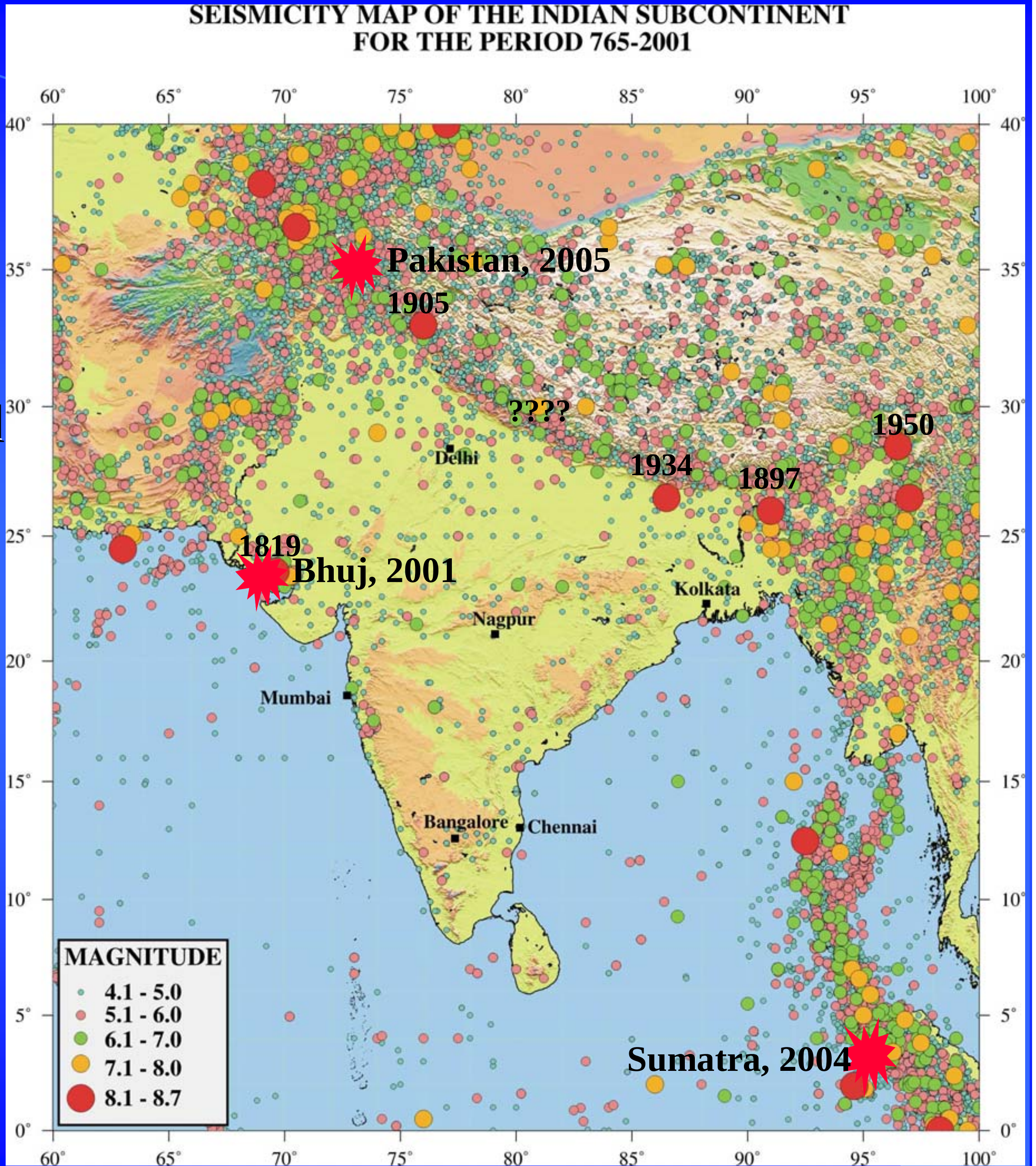
Bangalore, India

The Indian subcontinent has experienced 13 great events of magnitude greater than 8.0.

Within India, there are five such events occurred in the past 200 yrs.

- 1819 Kutch
- 1897 Shillong
- 1905 Kangra
- 1934 Bihar
- 1950 Assam



Earthquake Hazard Maps

The early version of earthquake hazard maps were called seismic zoning maps prepared on the basis of seismotectonic province, the premise being that earthquakes will repeat as in the past, with similar magnitudes and impacts.

The first seismic hazard zoning map of India, was brought out in **1956** by **Dr. A.N. Tondon**. It consisted of 3 zones based on the broad concept of space-time earthquake statistics and the prevailing understanding of geotectonics.

1. Least Hazard: **Indian shield in the south**
2. Most Hazard: **Himalayas, Chaman fault region, Indo-Burma region.**
3. Moderate Hazard: **The areas between the above two.**

Official Seismic zoning map of India

Bureau of Indian Standard (BIS) is the official agency for publishing the seismic zoning maps and codes in India

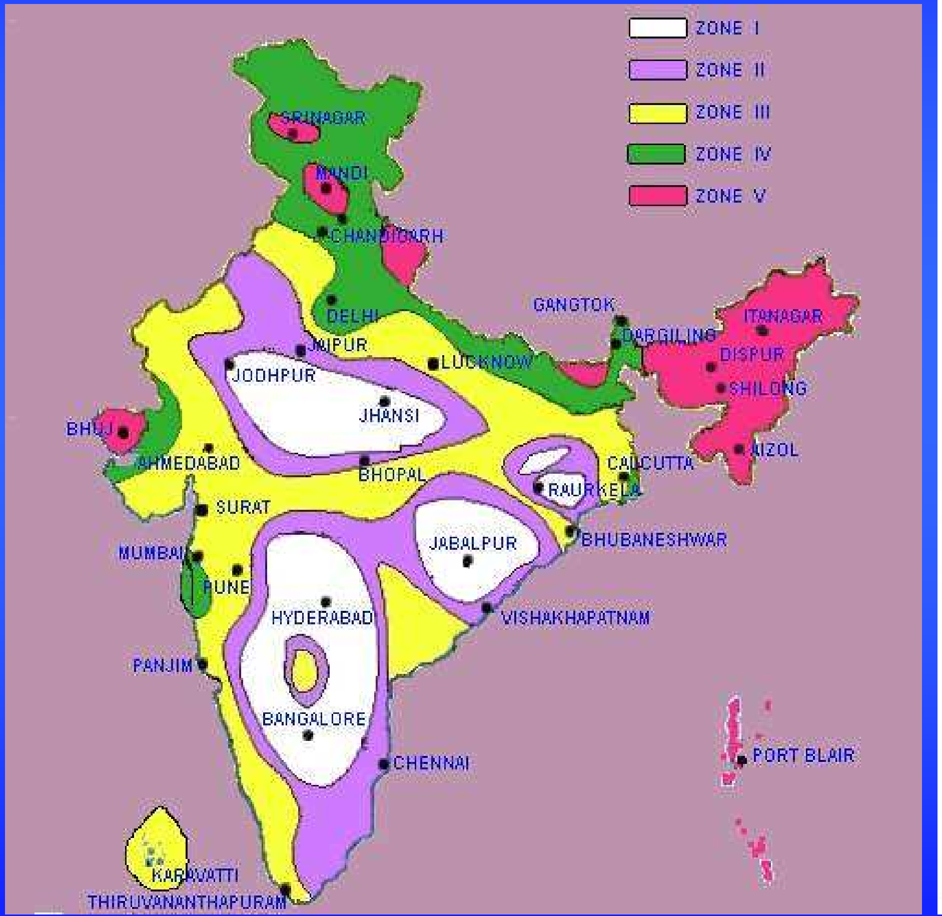
They brought out several hazard maps consisting of :

6 Zones	1962	7 Zones	1966
5 Zones	1970, 1984		

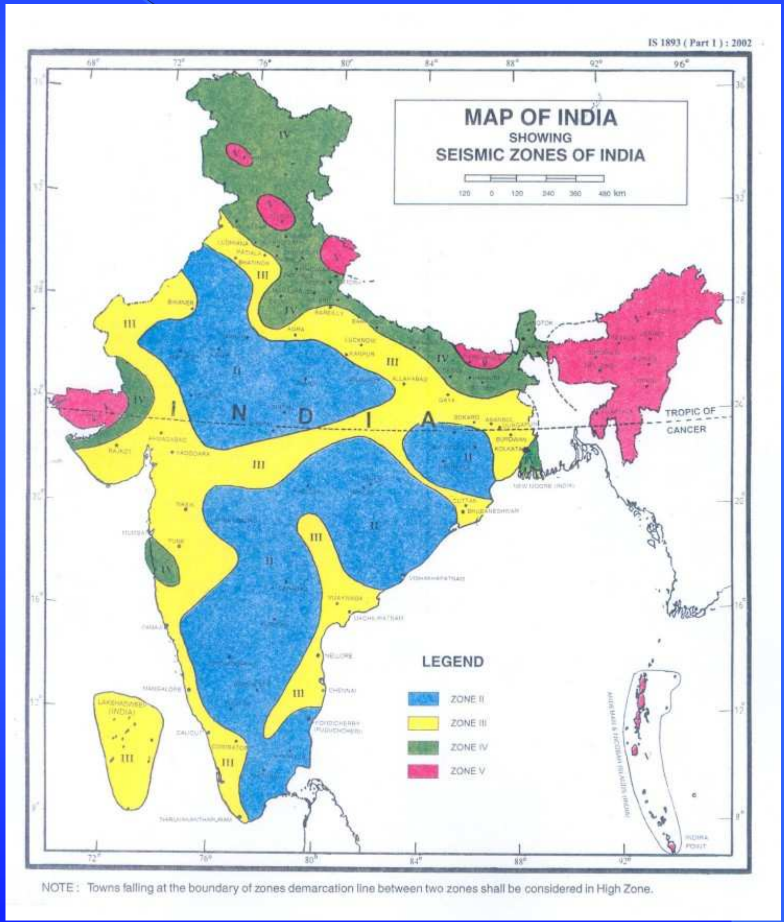
The recent seismic zoning map has been revised with only four zones, instead of five. Zone I has been merged to Zone II and hence Zone I does not appear in the new zoning; only Zones II, III, IV and V do. The Killari area has been included in Zone III and the Bellary isolated zone has been removed. The parts of eastern coast area have shown similar hazard to that of the Killari area, the level of Zone II has been enhanced to Zone III and connected with Zone III of Godawari Graben area.

SEISMIC ZONING MAP OF INDIA

Before 2002



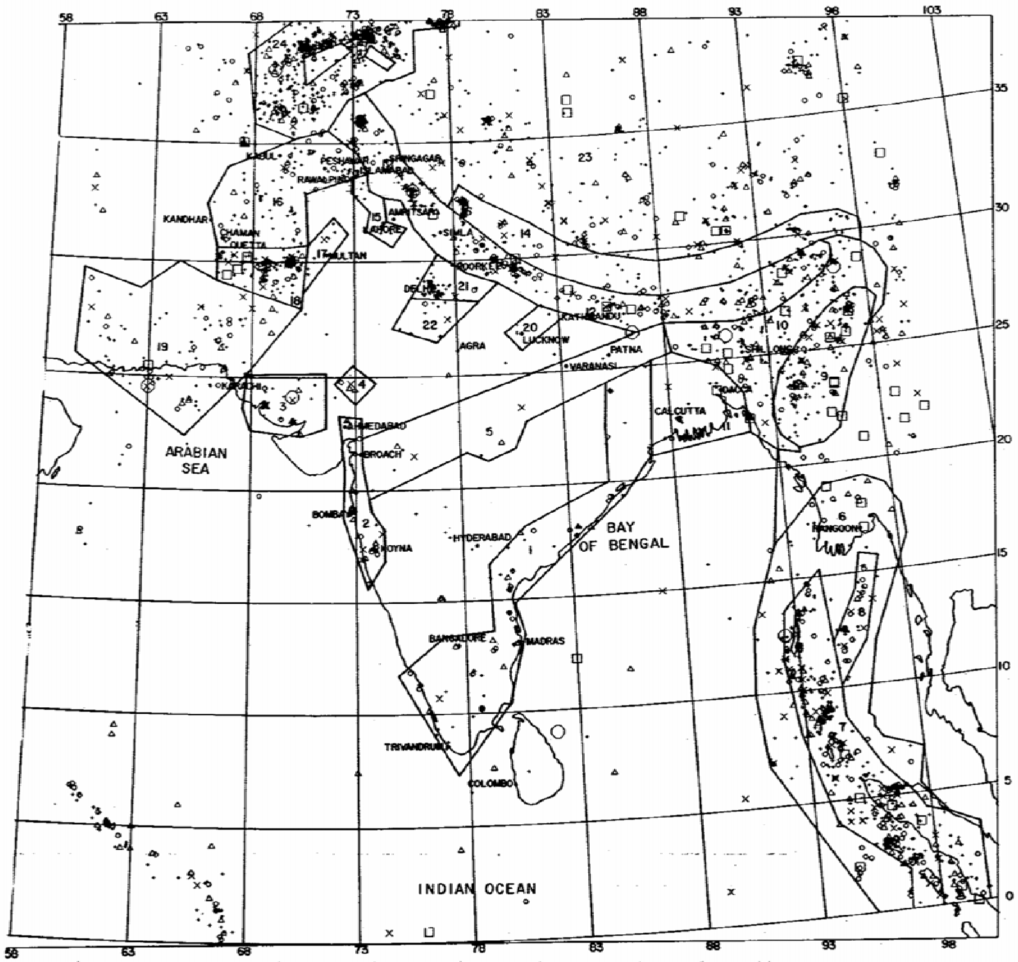
Latest



Probabilistic Hazard Map

By: Khattri et al., 1984, Tectonophysics

- 24 Seismogenic Zones
- Intensity-distance relation compared with United States and Eastern U.S. Attenuation law by Algermissen & Perkins, 1976 is chosen



Probabilistic Hazard Map

By: Khattri et al., 1984, Tectonophysics

pp. 129–130

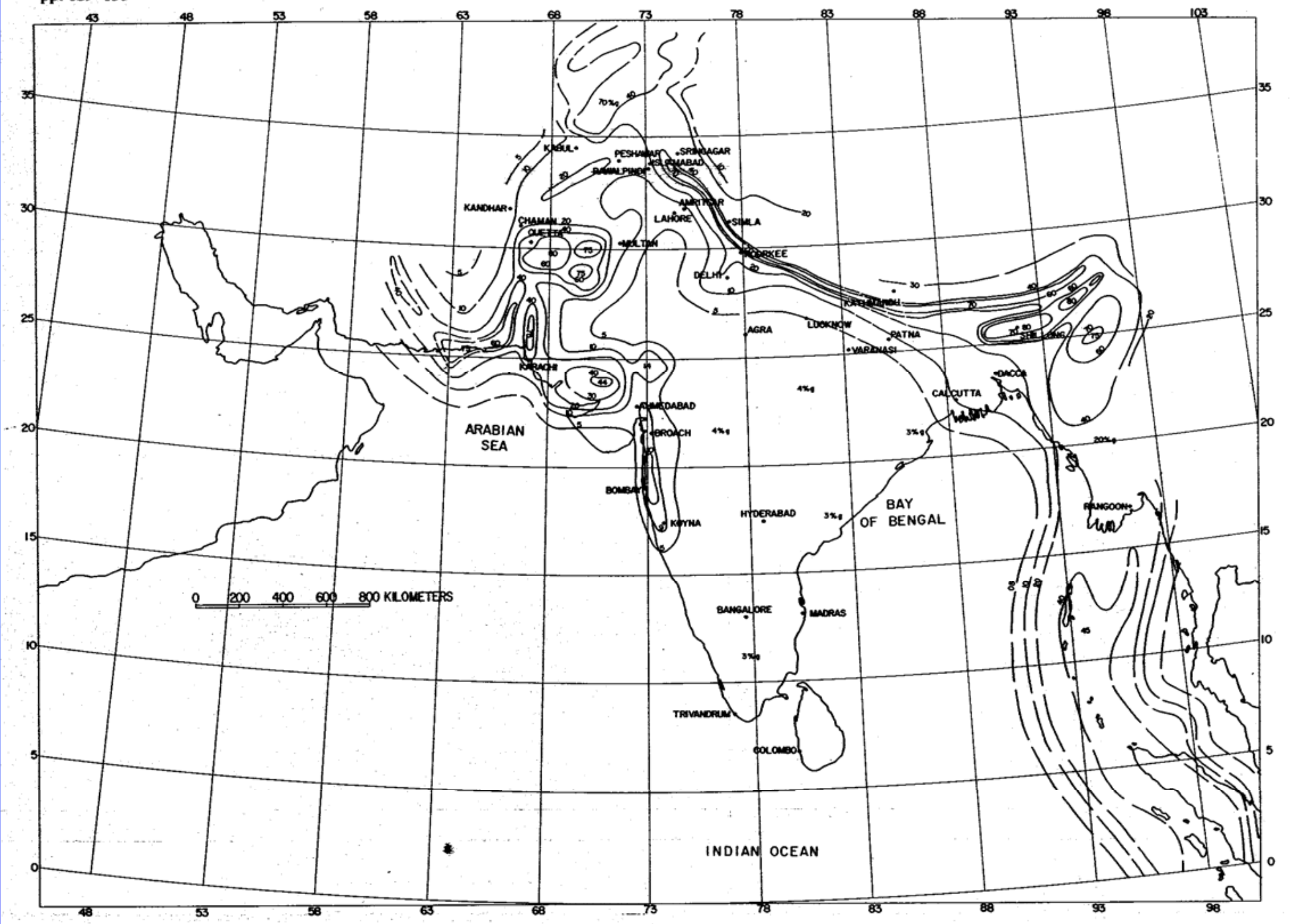
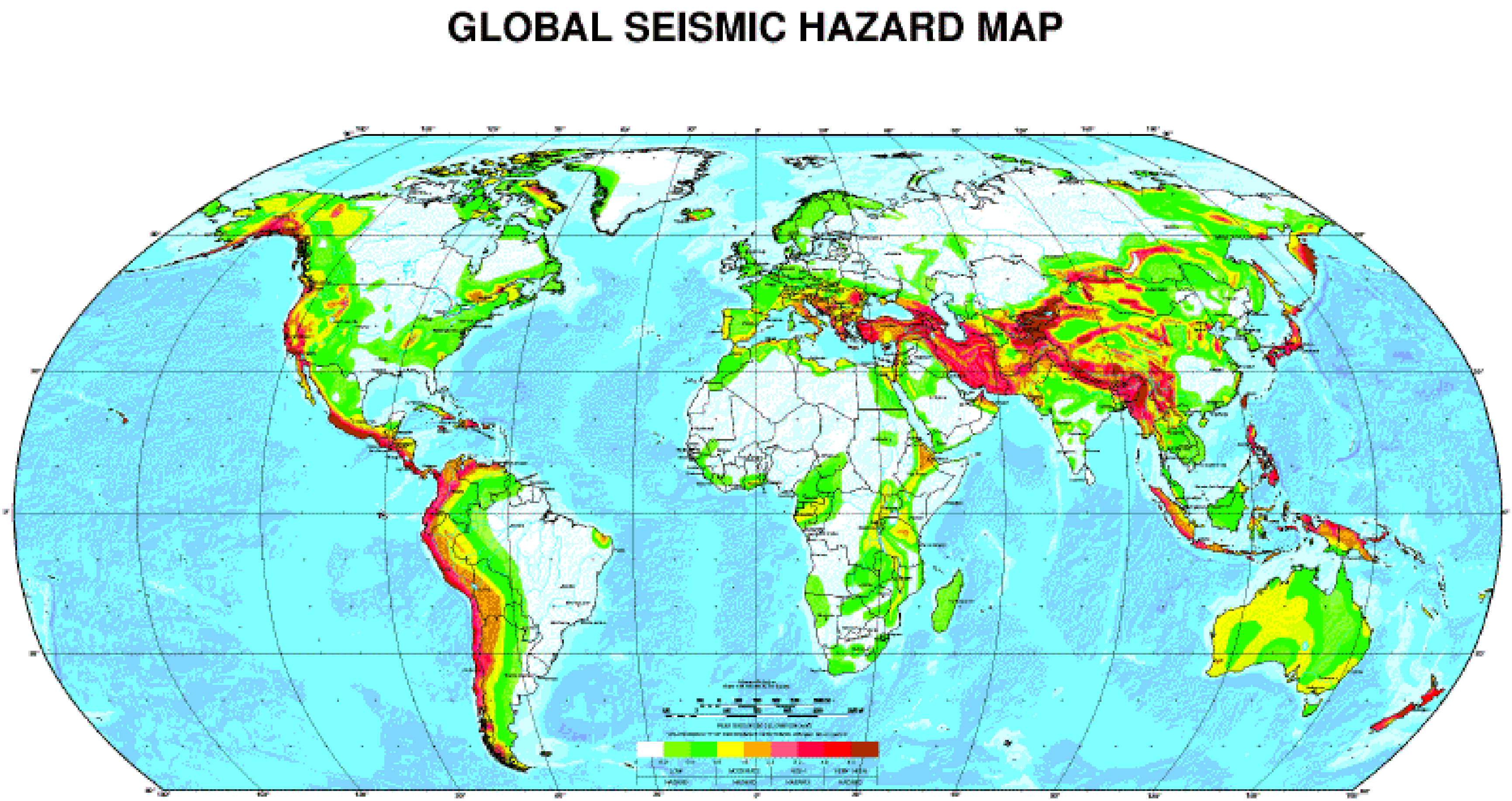


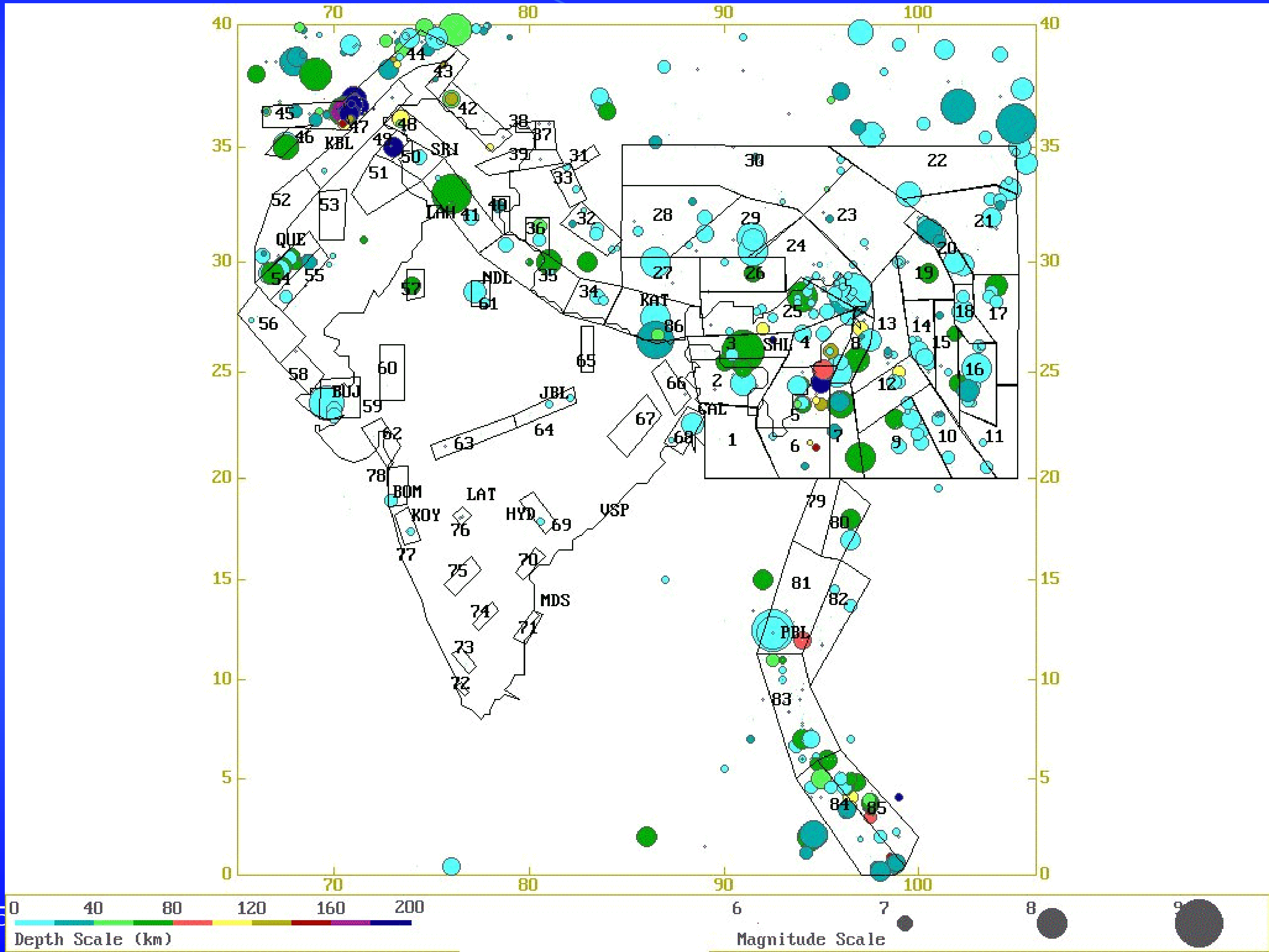
Fig. 11. The seismic hazard map for India and neighboring areas showing contours of expected peak accelerations in rock in percent *g*. The exposure period for this map is 50 years. The probability of exceedence of the mapped accelerations in 50 years in 10%. The return period of the peak acceleraions is 475 years.

GLOBAL SEISMIC HAZARD ASSESSMENT PROGRAM (GSHAP)

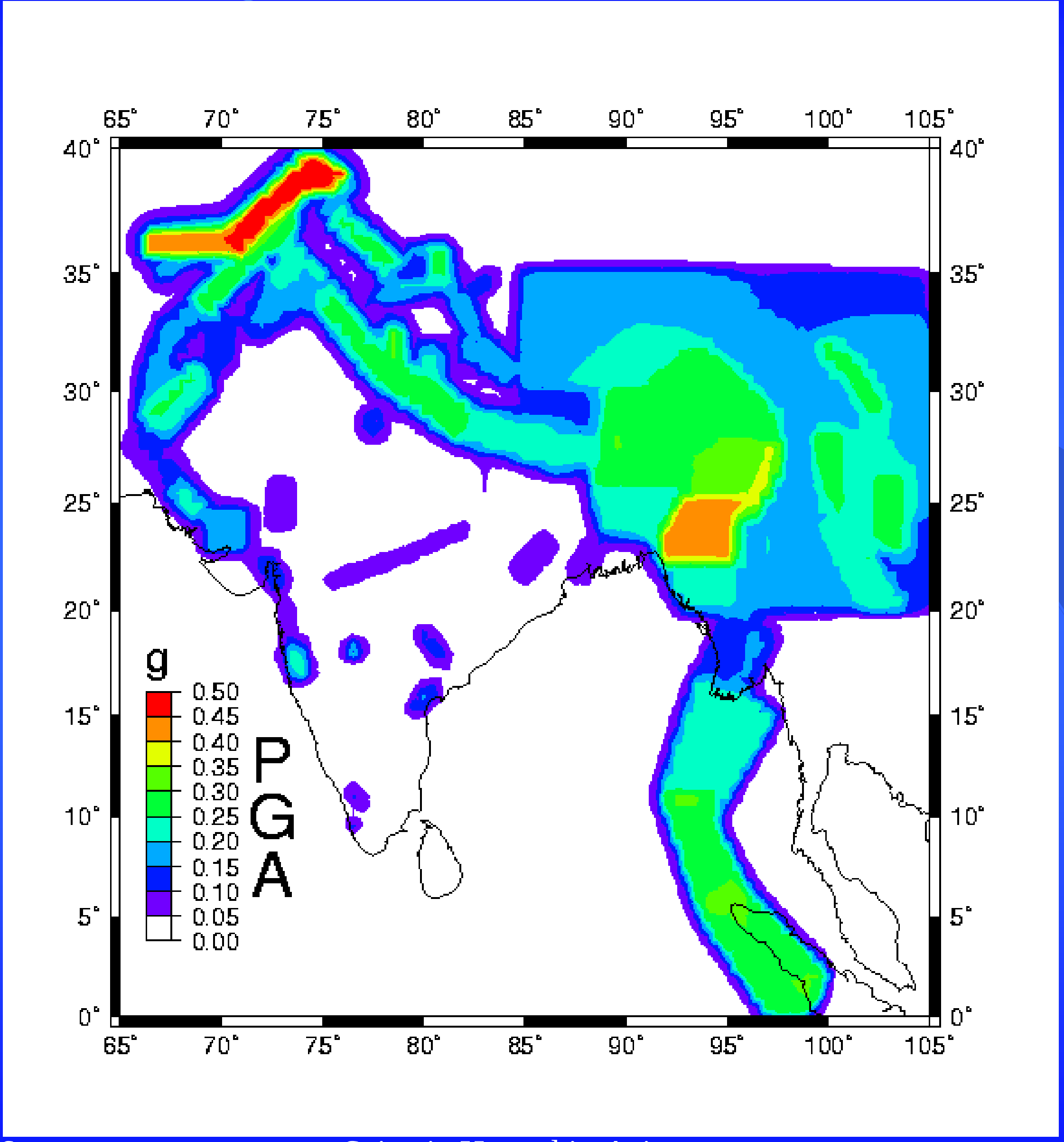


GSHAP in Indian subcontinent,

Bhatia et al., 1999, Annali di Geofisica

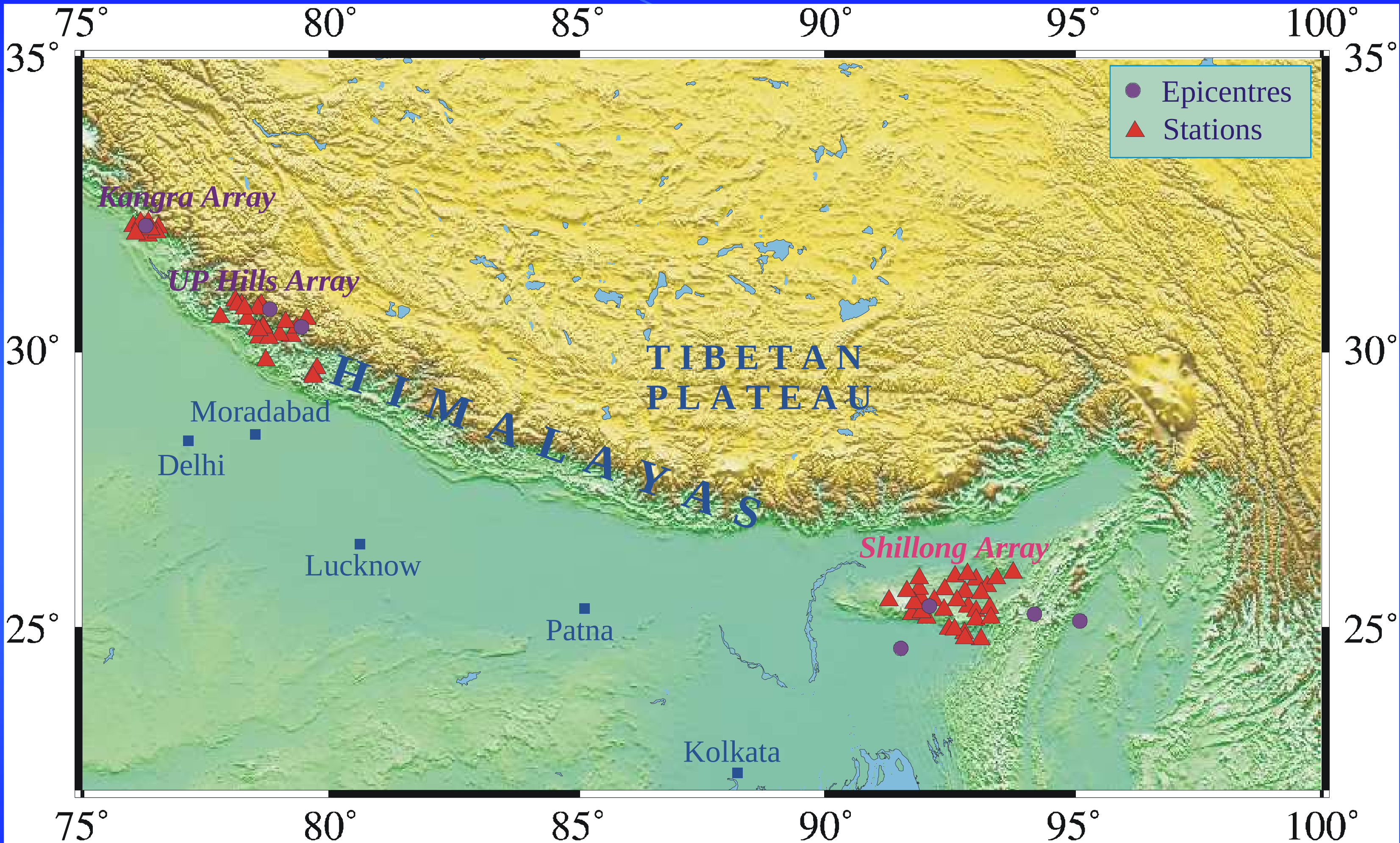


GSHAP in Indian subcontinent Contd…..



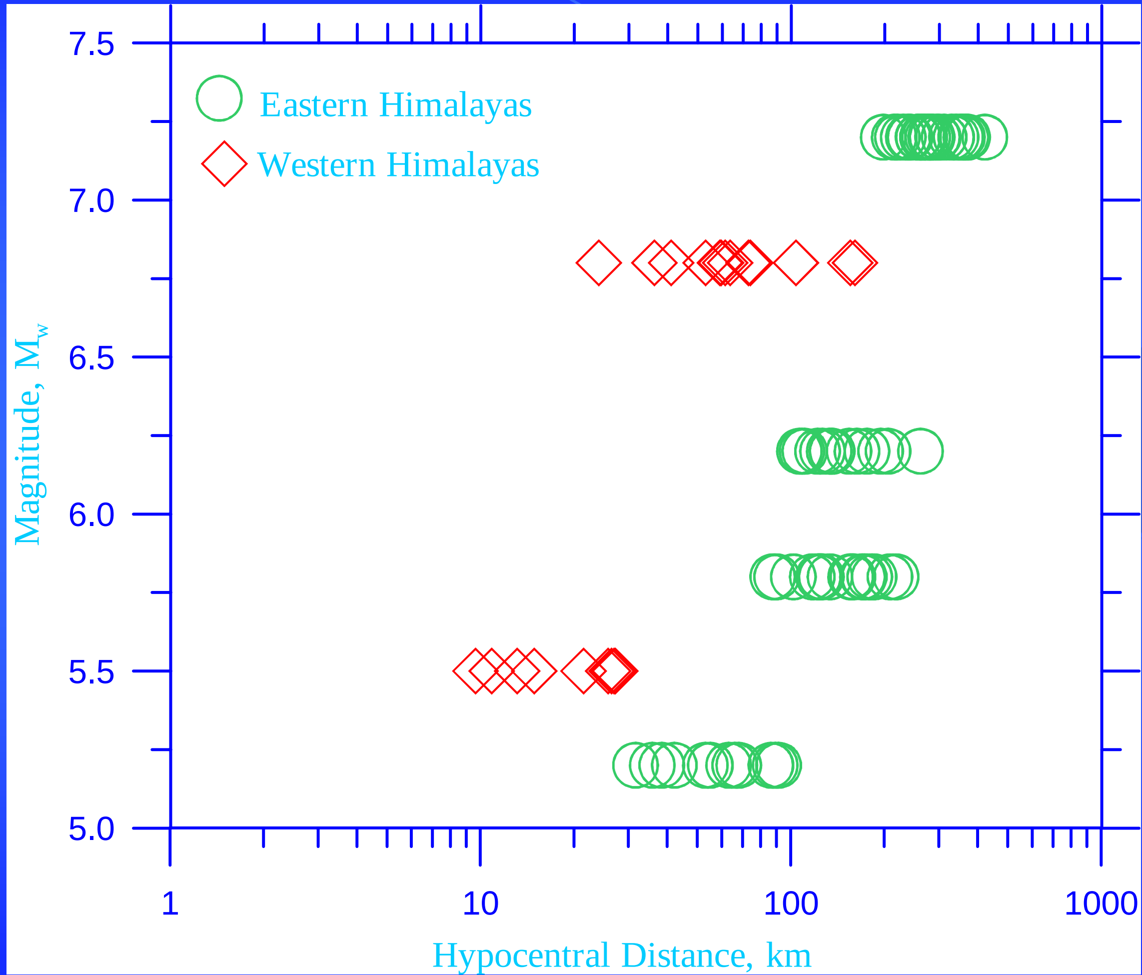
A recent study on Attenuation law

Parvez et al., 2001, GJI

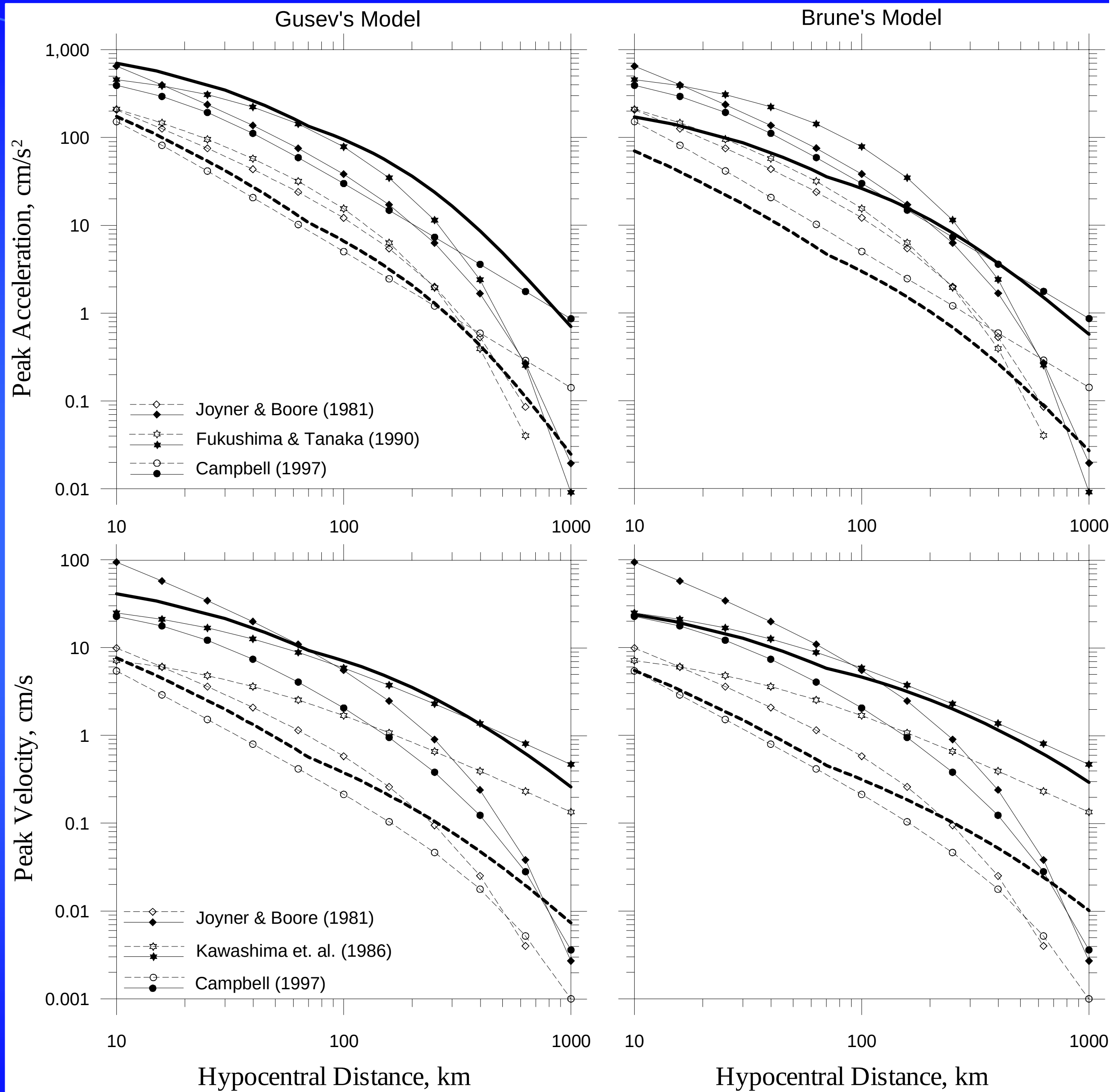


Strong motion arrays and epicenter of recorded events

Data distribution with distance



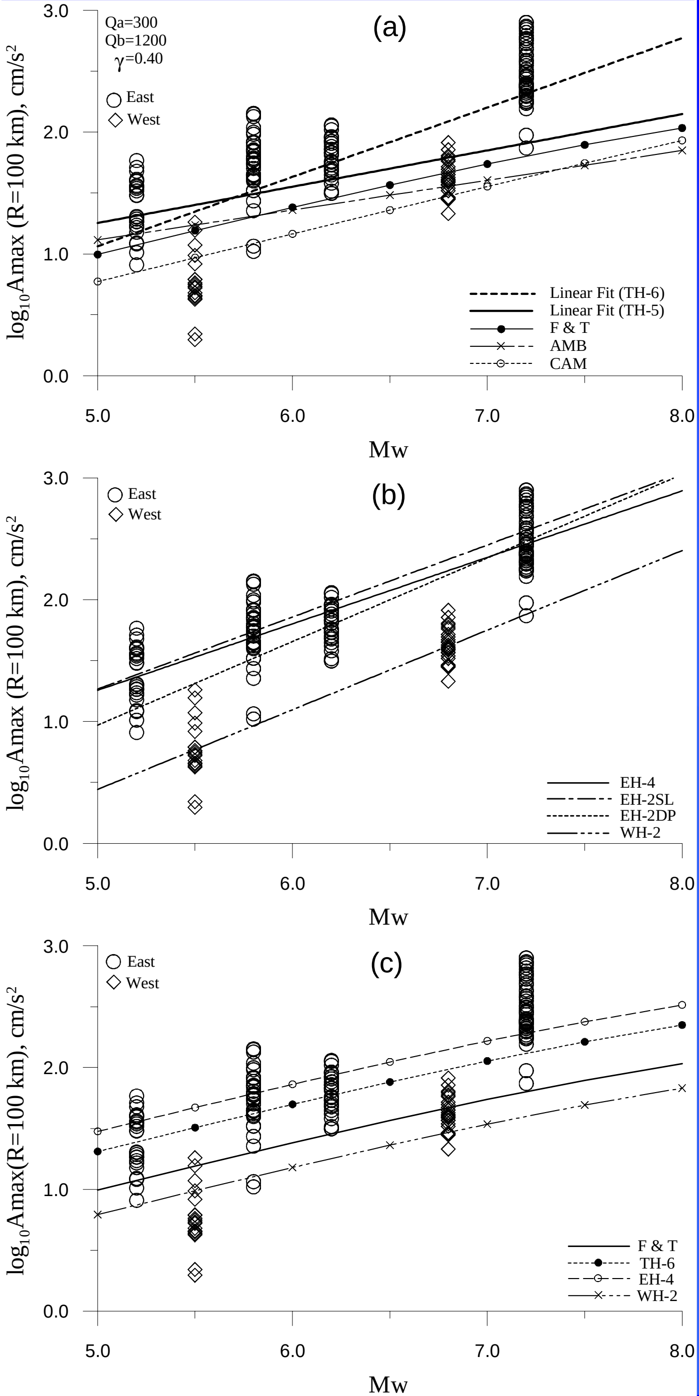
In the strong motion data analysis, instead of empirical formulae, we performed the reduction of the observations to a fixed distance and magnitude using independently defined distance and magnitude trends.



The plot of peak horizontal acceleration reduced at 100 km distances versus moment magnitude and the regression

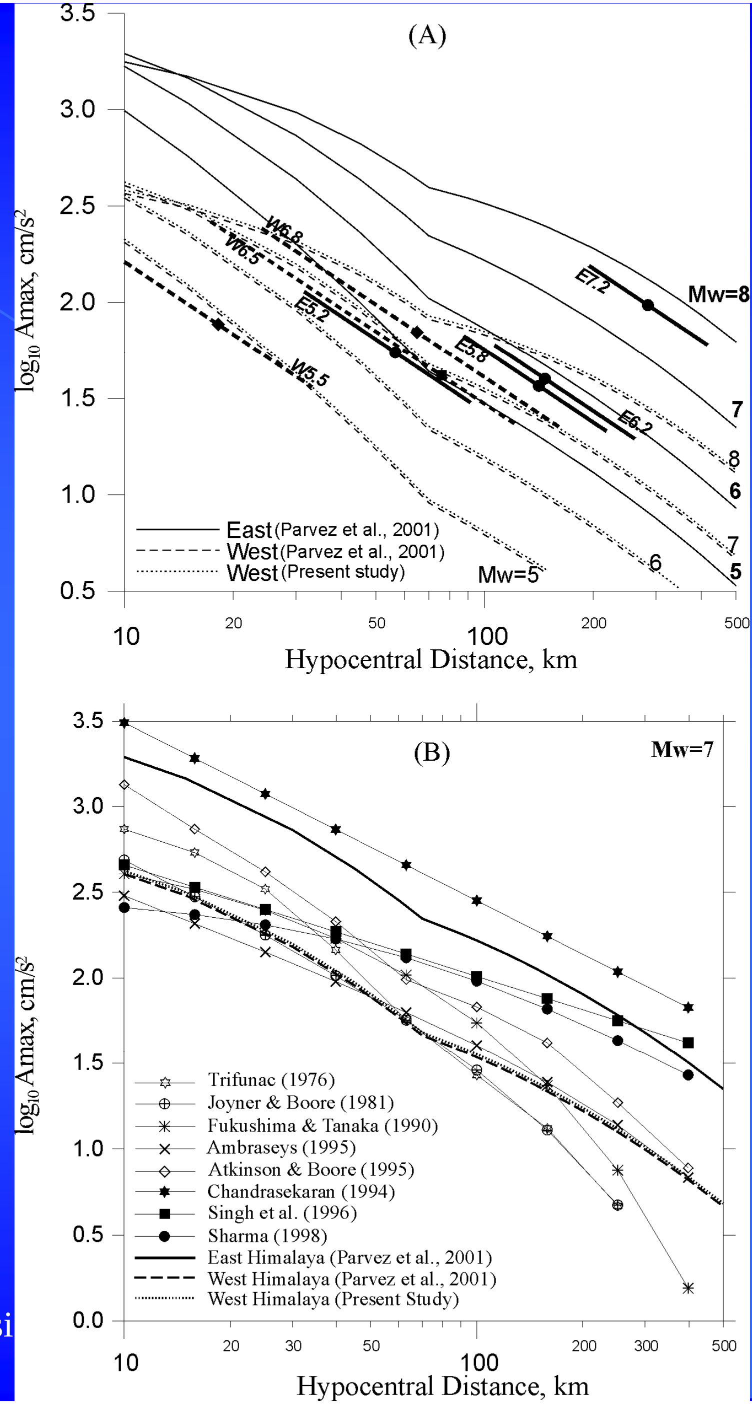
The plot of peak horizontal acceleration reduced at 100 km distances versus moment magnitude and the regression after separating in Eastern and Western parts.

The plot of peak horizontal acceleration reduced at 100 km distances and at Mw=7.0 using Fukushima and Tanaka, 1990 versus moment magnitude and the regression

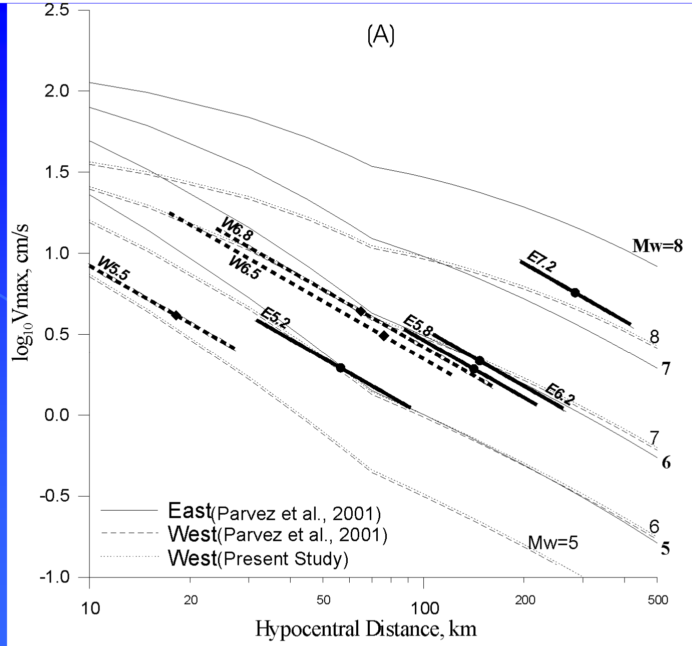


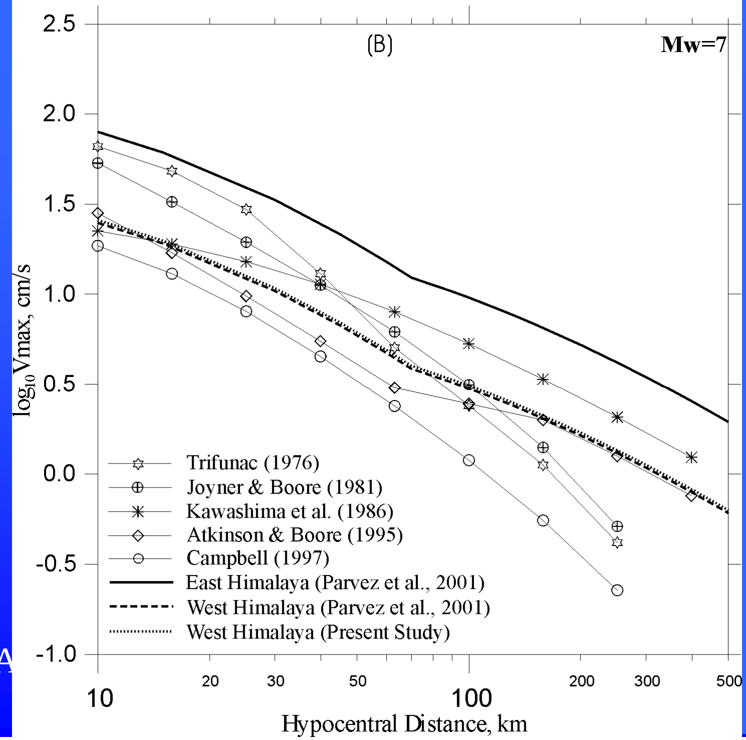
Finally we divided the data into two geographical groups eastern and western sub-regions based on the residual variance and attenuation law is established using spectral energy propagation/random function approach of Gusev (1983).

The important outcome of this study is the presence of unusually high levels of epicentral amplitudes for eastern sub-region which is almost three times that of western region.

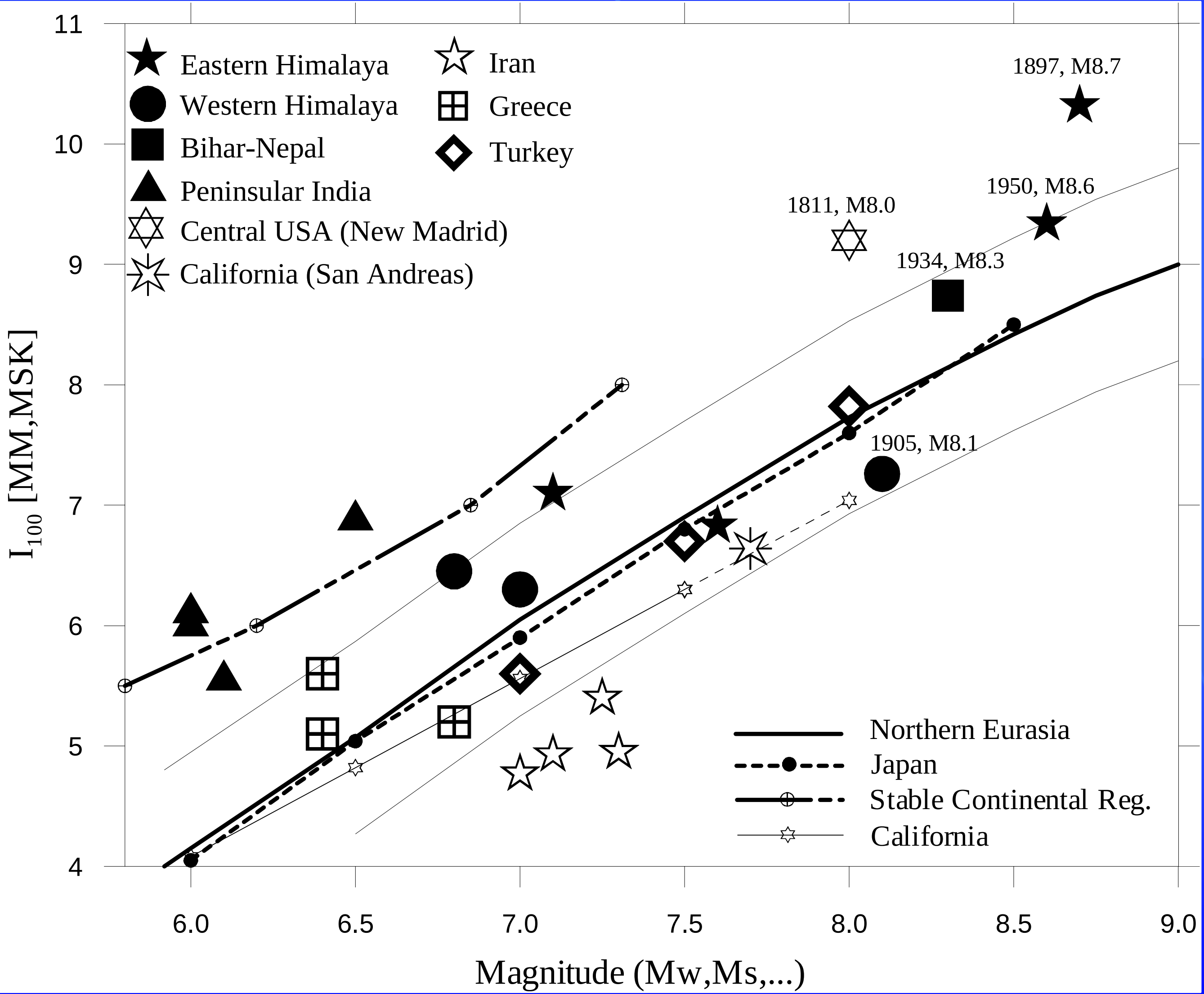


Similar trend was seen for peak Velocity attenuation





Comparison of I_{100} (Intensity at 100 km) of Indian earthquakes and other seismogenic zone of the world.



Deterministic Seismic Hazard in India and Adjacent Areas

Parvez et al., 2003, GJI

1. Instead of using extremely dense set of recording instruments and then waiting for strong earthquakes to occur in likely focal regions to measure ground motion, it is wise to go for realistic modelling of ground motion with the available geological, geophysical, seismological and seismotectonic data applying modern theories for the forward and the inverse problems using available high memories and fast computers.

2. A complete database of predicted strong motion histories for all sites and possible focal mechanisms can be constructed. This database can then, naturally, updated continuously by comparison with incoming new experimental data

The Input Parameters used for deterministic Hazard

(Costa et al., 1993; Panza et al., 1999)

SEISMOGENIC SOURCE ZONE

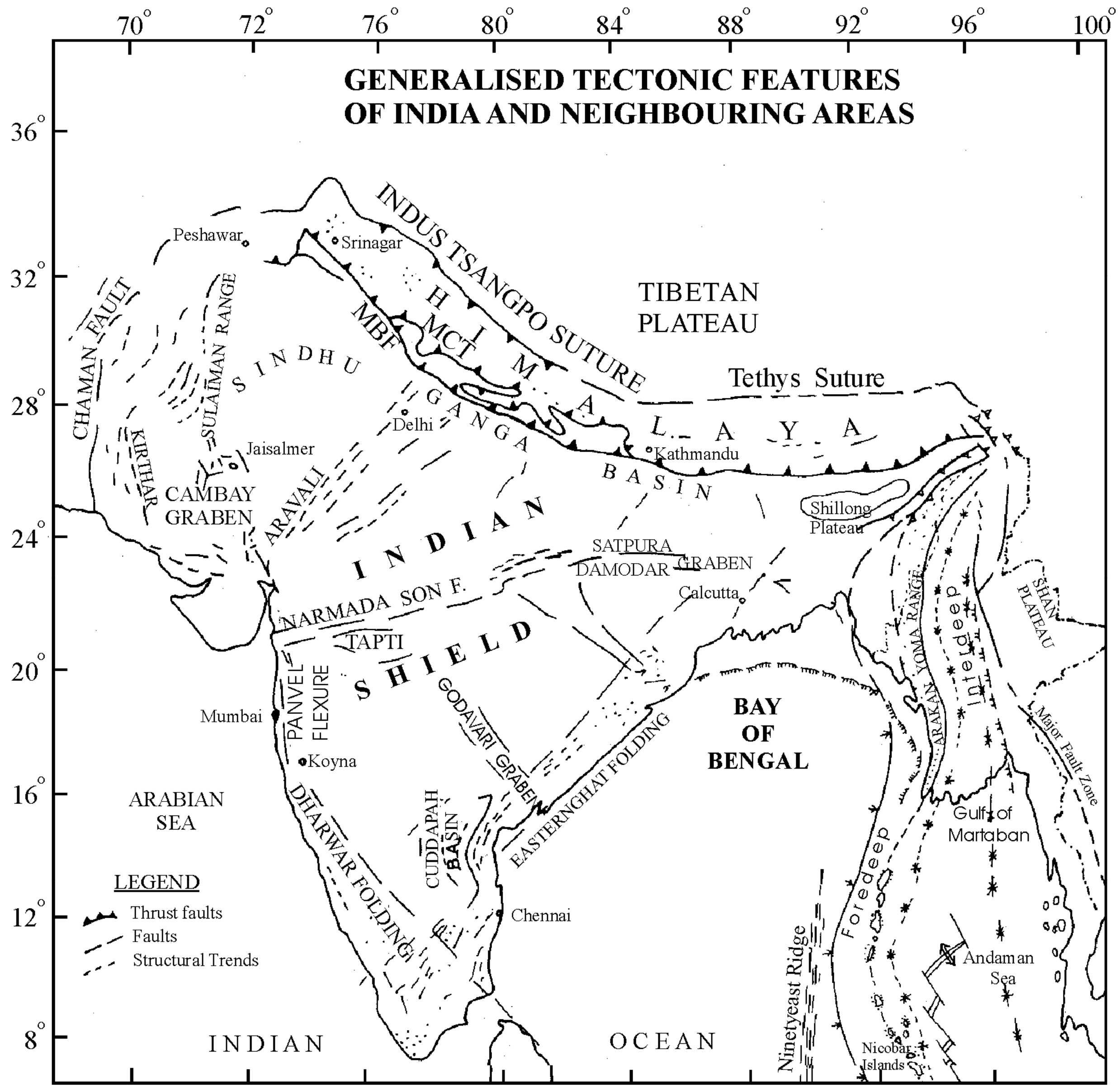
STRUCTURAL MODEL

(V_p, V_s, Q_p, Q_s, ρ)

FAULT PLANE SOLUTION

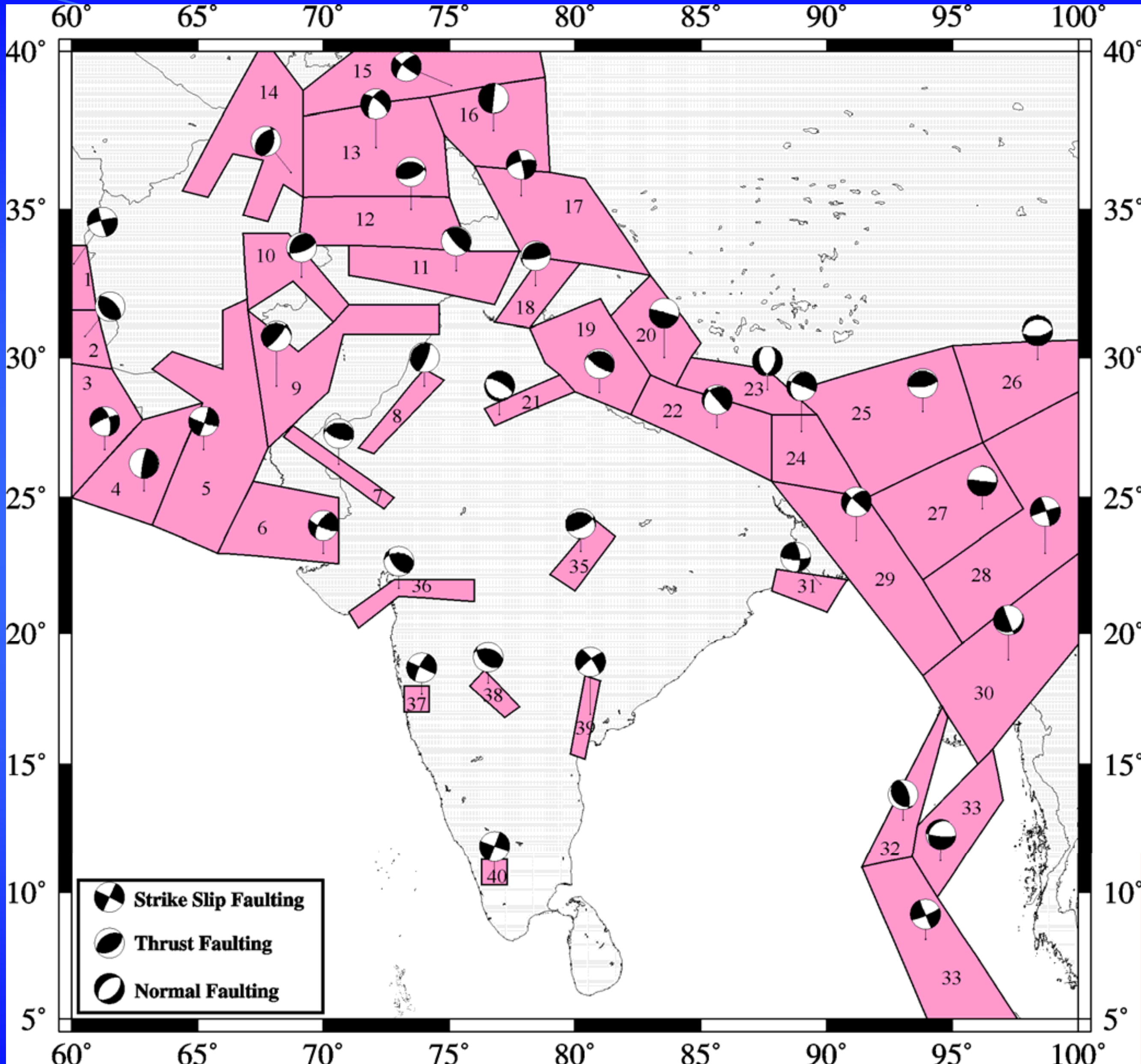
EARTHQUAKE CATALOGUE

General Geological and Tectonic map of the Indian Subcontinent

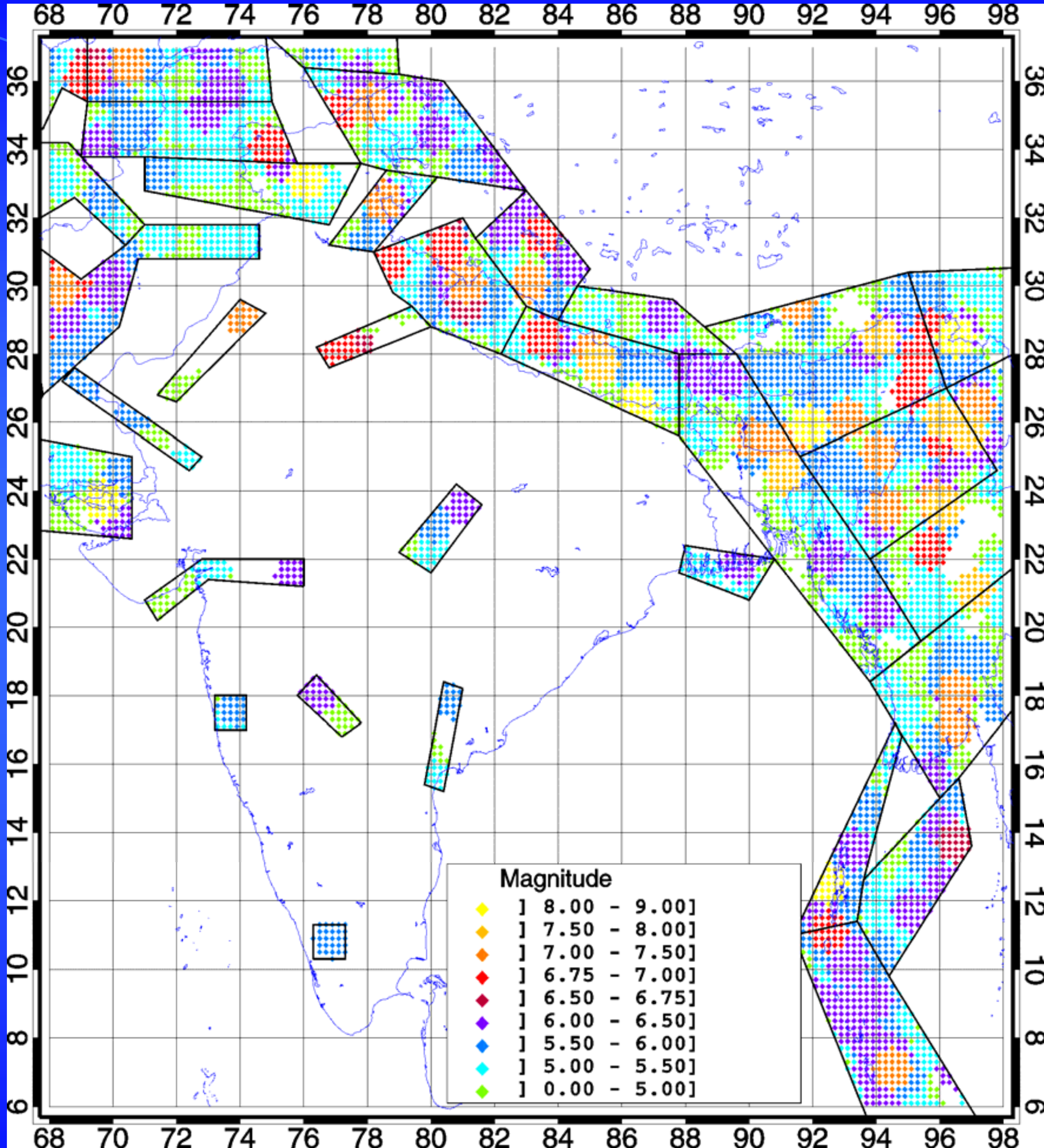


5 December 2006

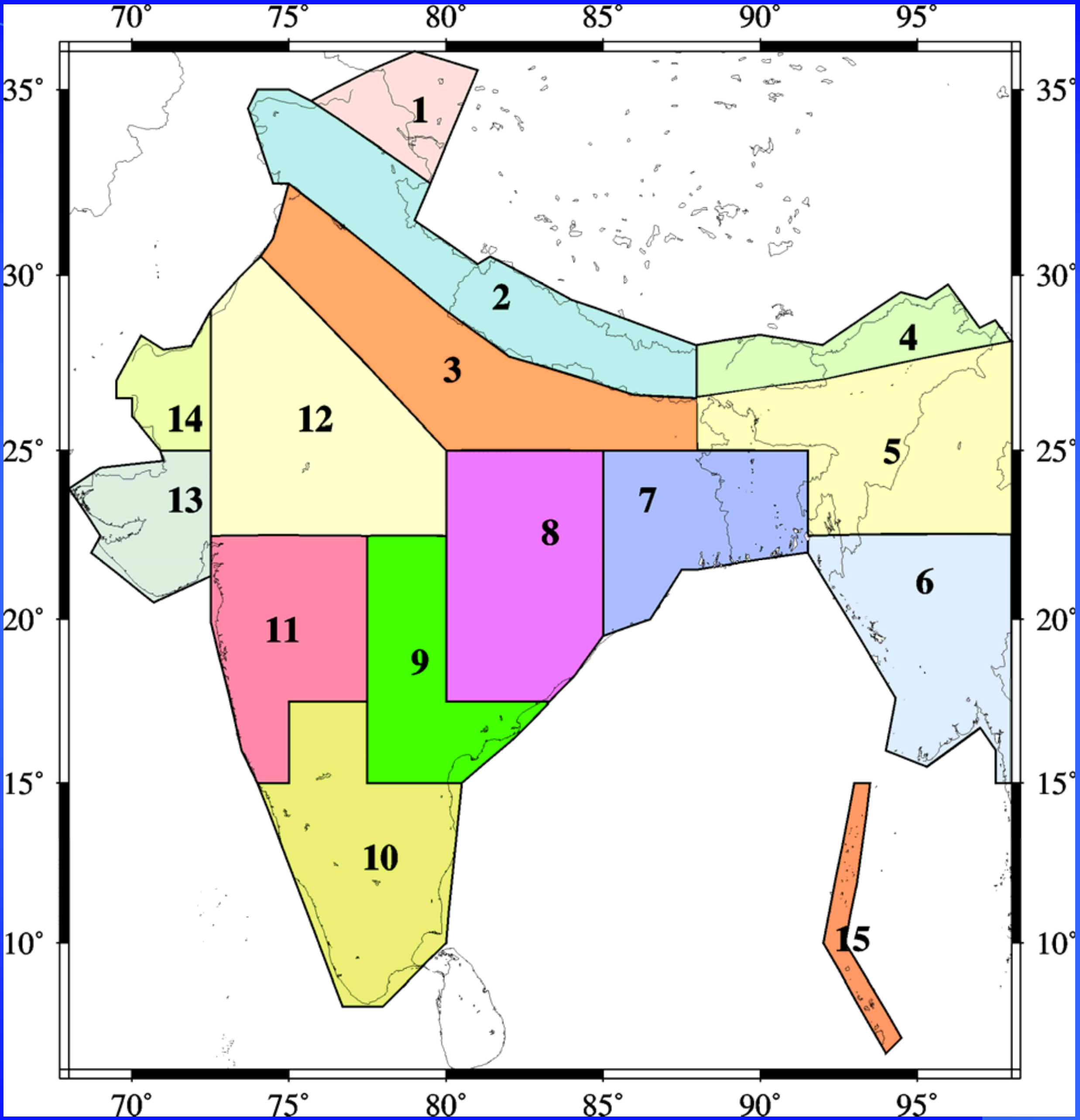
40 Seismogenic Zones drawn on the basis of clustering of events, geology and tectonics



The seismicity map obtained from the earthquake catalogue has been smoothed into a grid cell of 0.2^{0}x0.2^0 (lat. and long.) by applying a centered smoothing window. After the smoothing of seismicity, only the sources falling within the seismogenic zones are taken into account for the computation of synthetic seismograms.

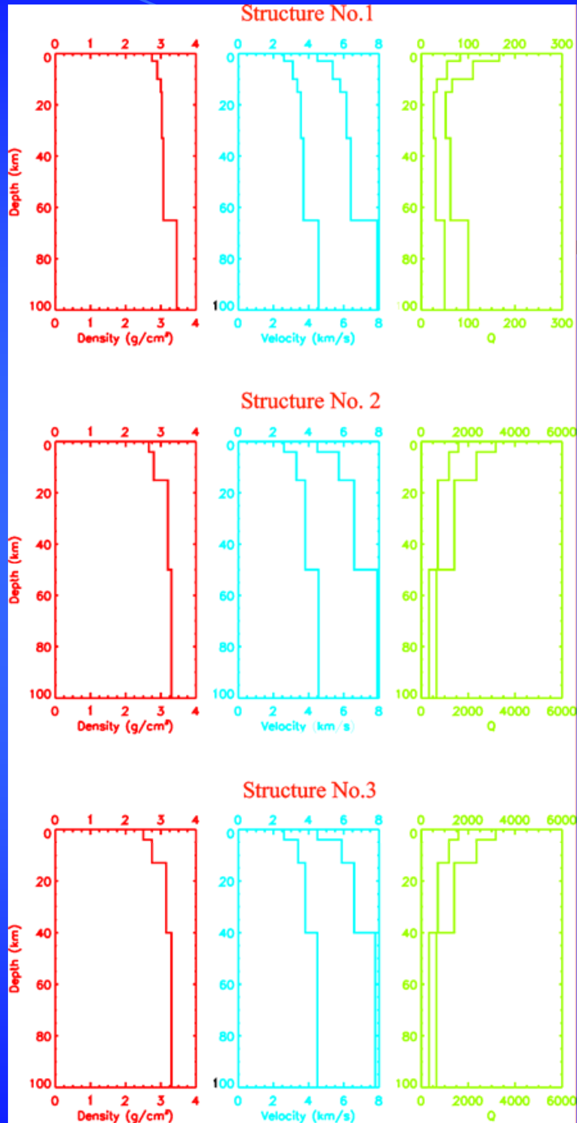


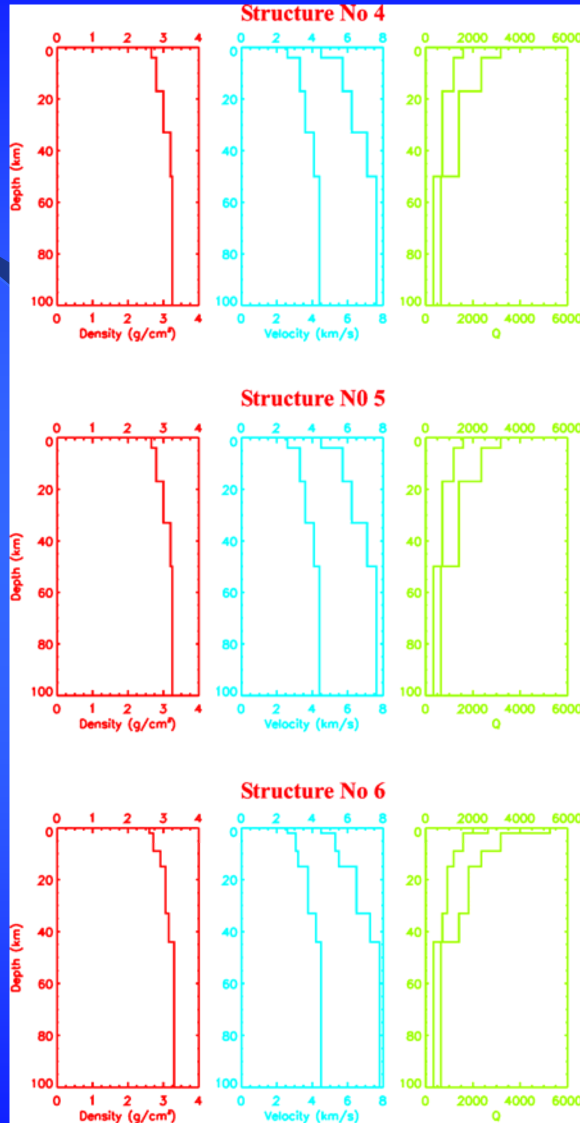
The boundaries of regional structural polygons that separate areas characterized by different lithopsheric properties. Each polygon is described by the number of flat layers with thickness, density, P- and S-wave velocities and corresponding Q values at the bedrock level.

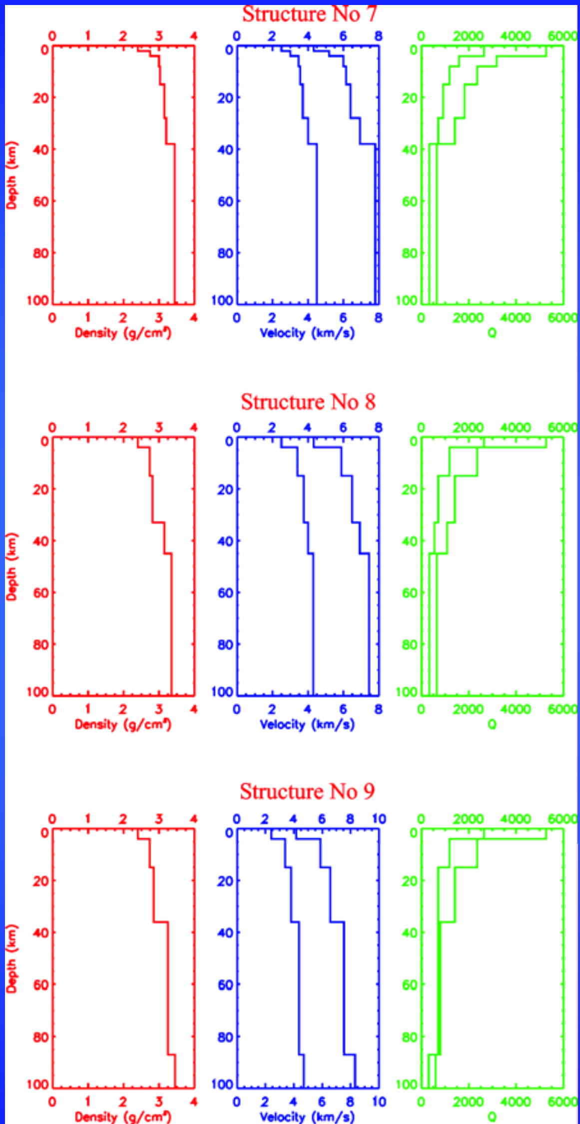


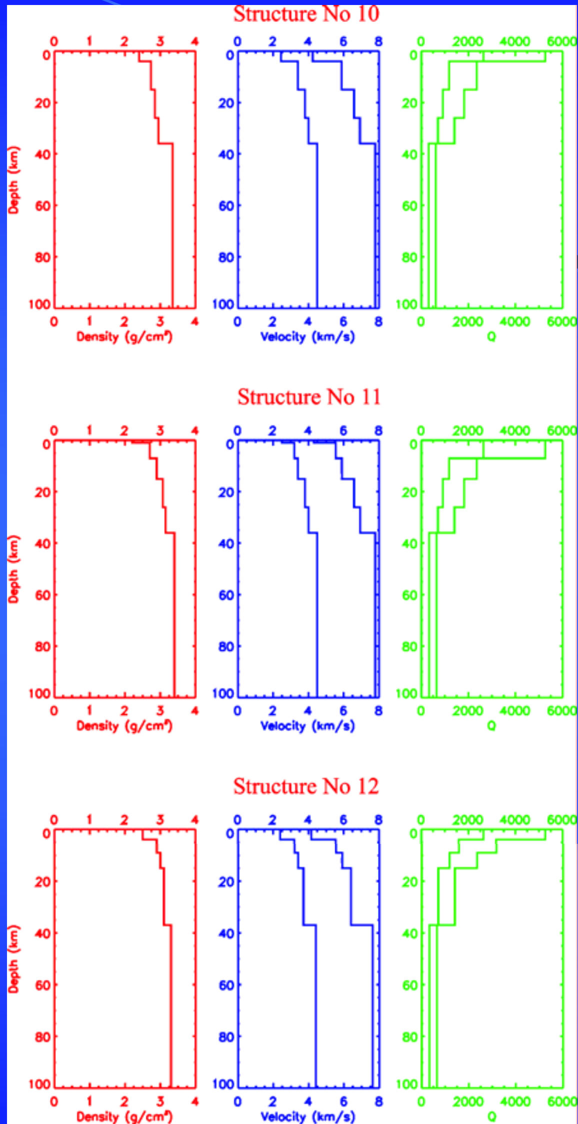
5 December 2006

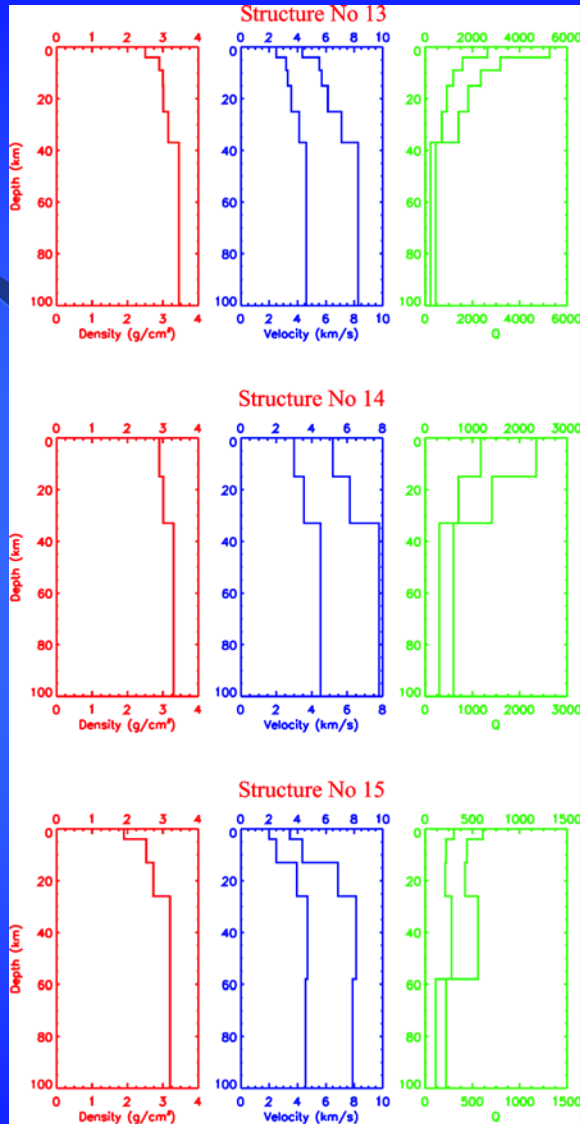
The average lithospheric structures for the regional structural polygons shown in the previous slide. Density in g cm^{-3}, P- and S-wave velocities in km s^{-1}, and the corresponding quality factor are shown for the first 100 km of depth.



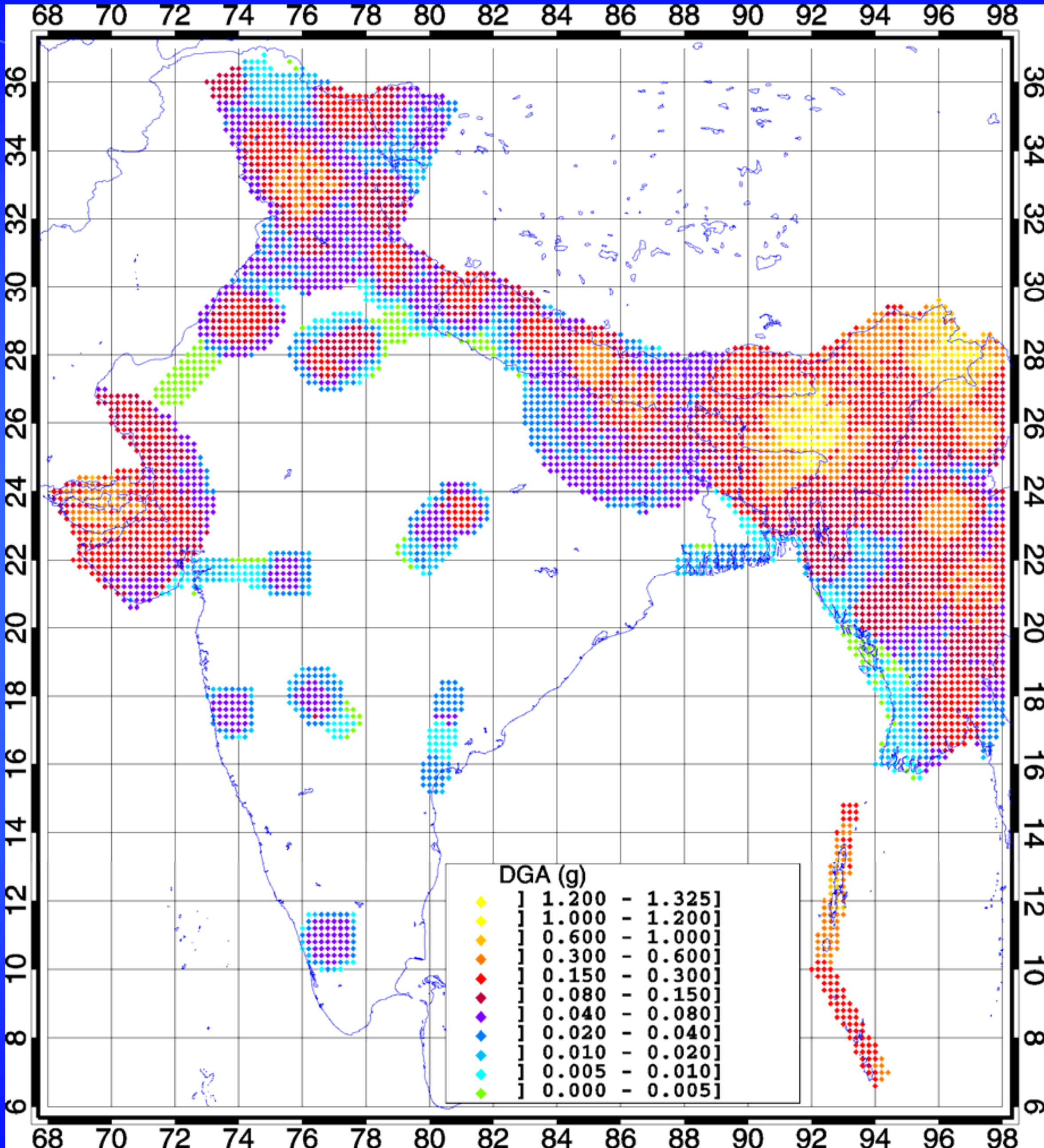



Structure No 7
Structure No 8
Structure No 9
Depth (km)
Density (g/cm³)
Velocity (km/s)
Q

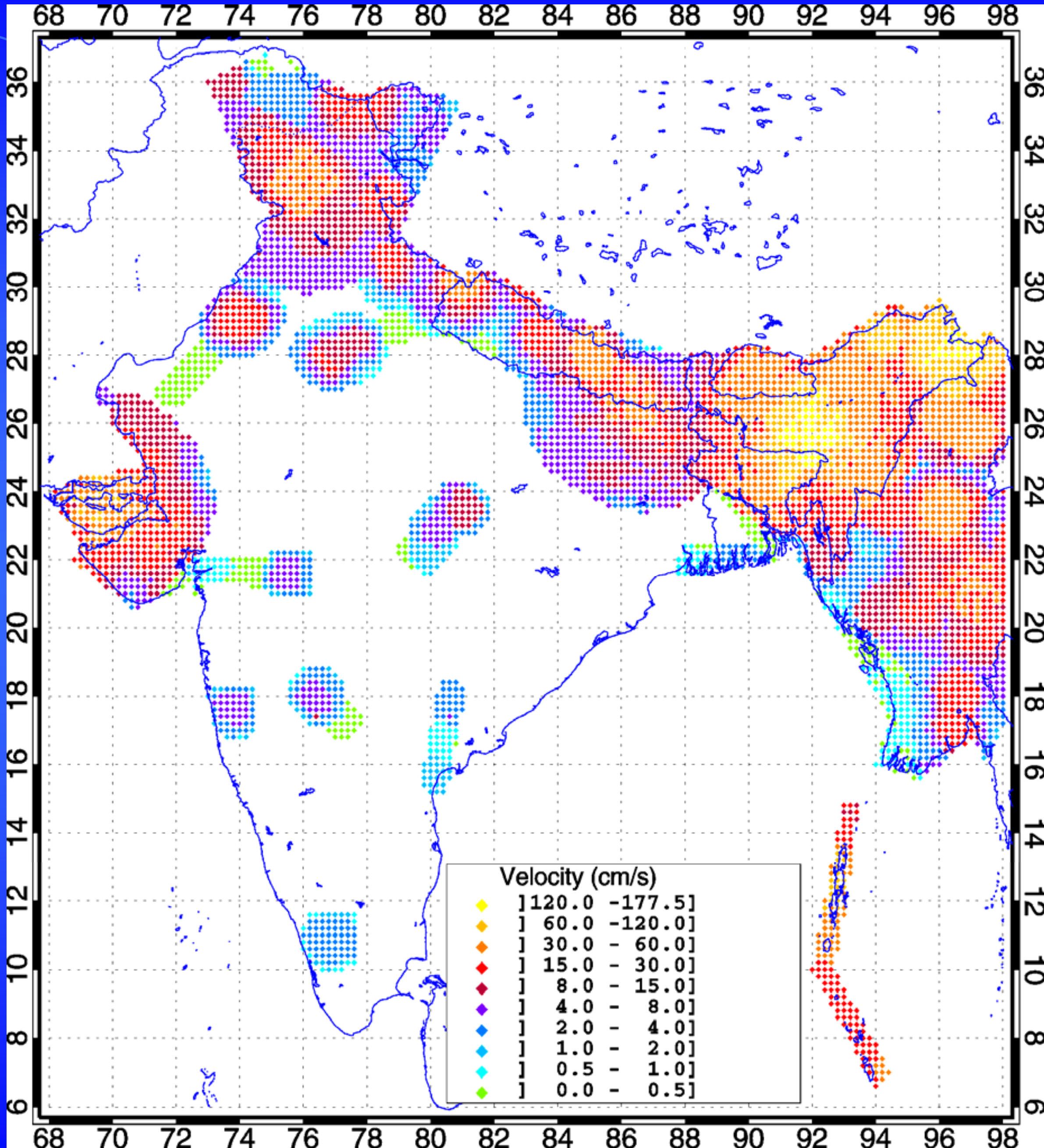

Structure No 10
Structure No 11
Structure No 12
Depth (km)
Density (g/cm³)
Velocity (km/s)
Q


Structure No 13
Structure No 14
Structure No 15
Depth (km)
Density (g/cm³)
Velocity (km/s)
Q

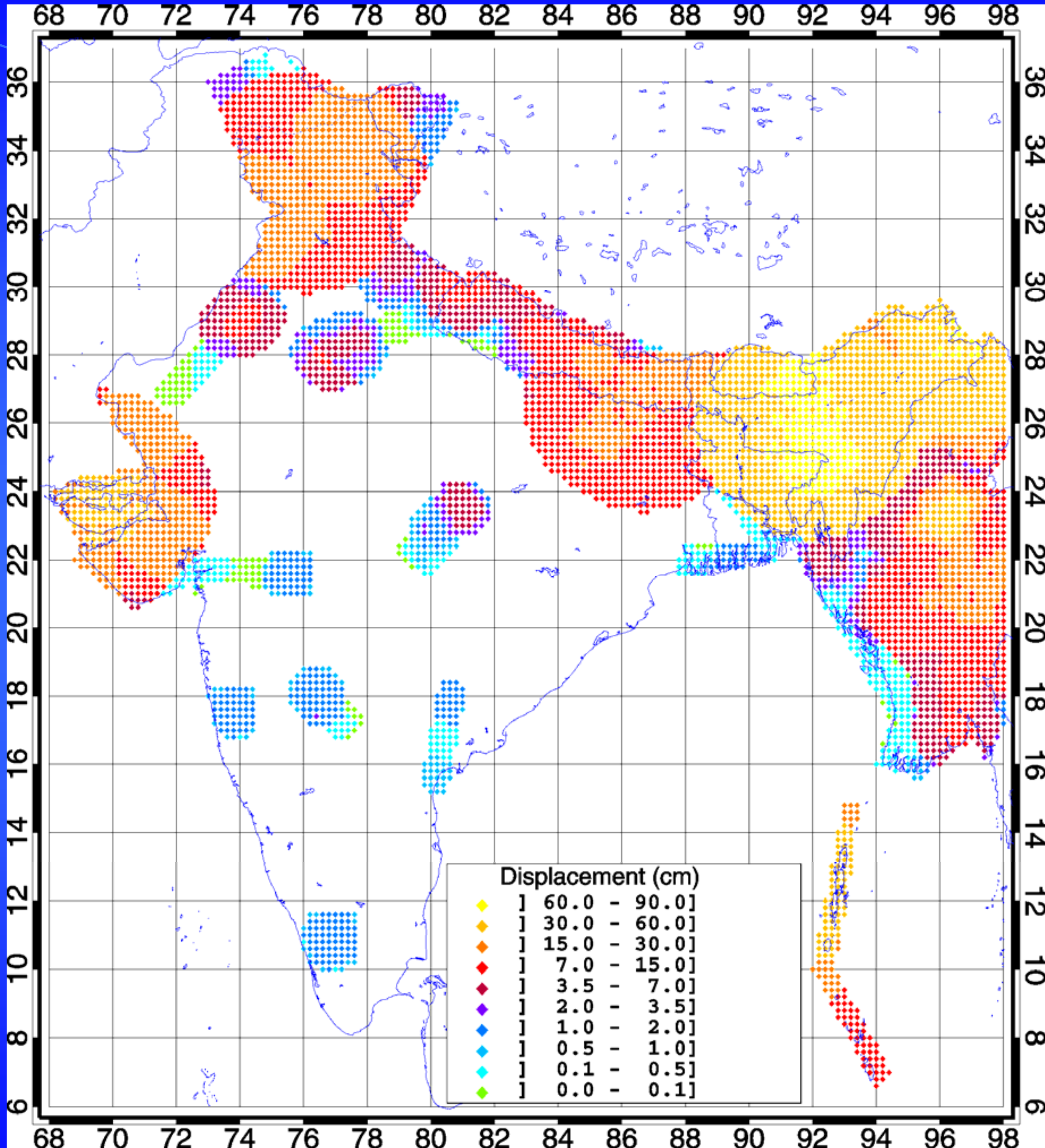
The final hazard map showing the Design Ground Acceleration (DGA)



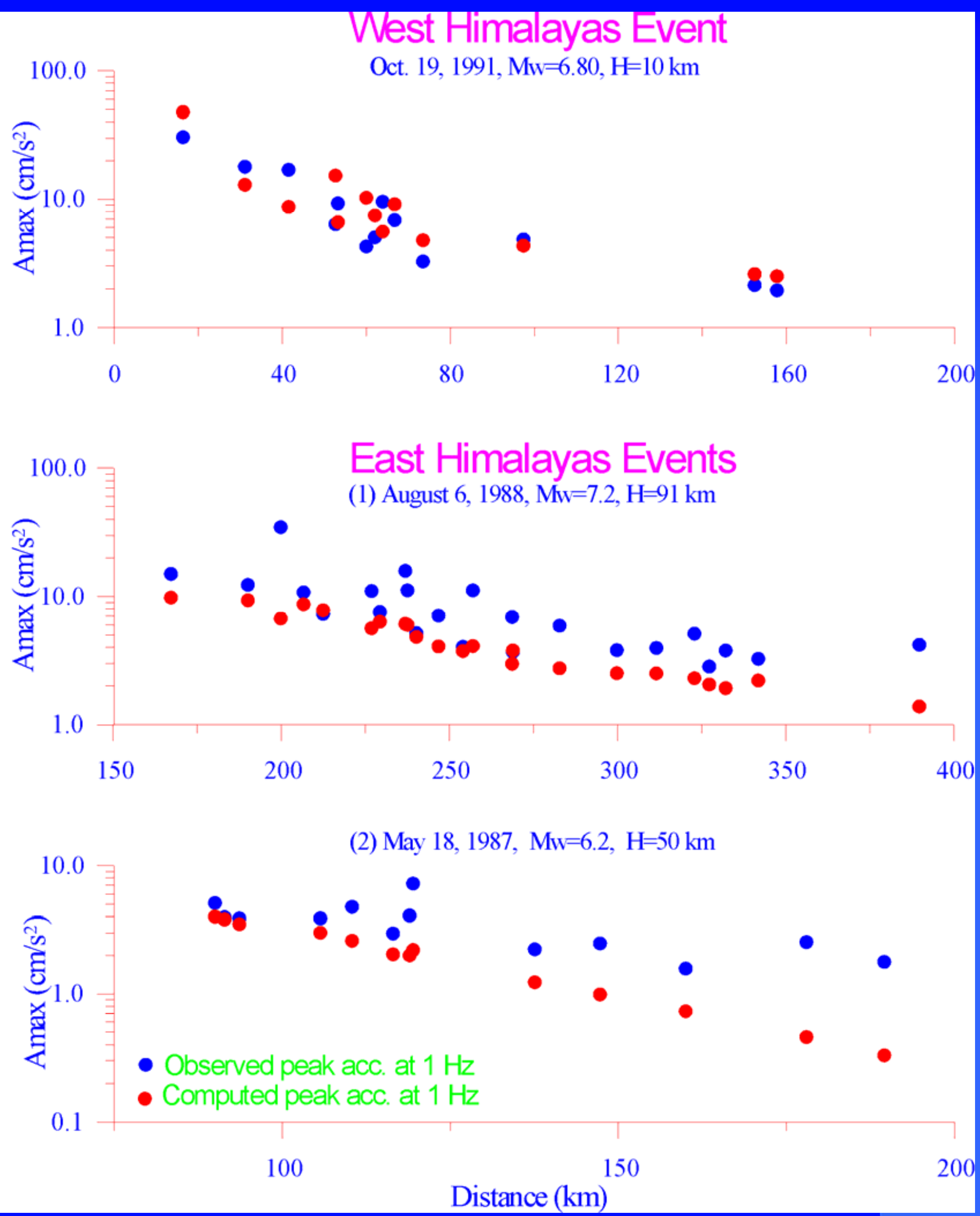
The final hazard map showing the peak velocity (VMAX)



The final hazard map showing the peak displacement (DMAX)



Comparison and validation of the synthetic signals with the observed strong motion amplitudes in three earthquakes of Himalayan region



Microzonation and Site Specific Ground Motion Modelling

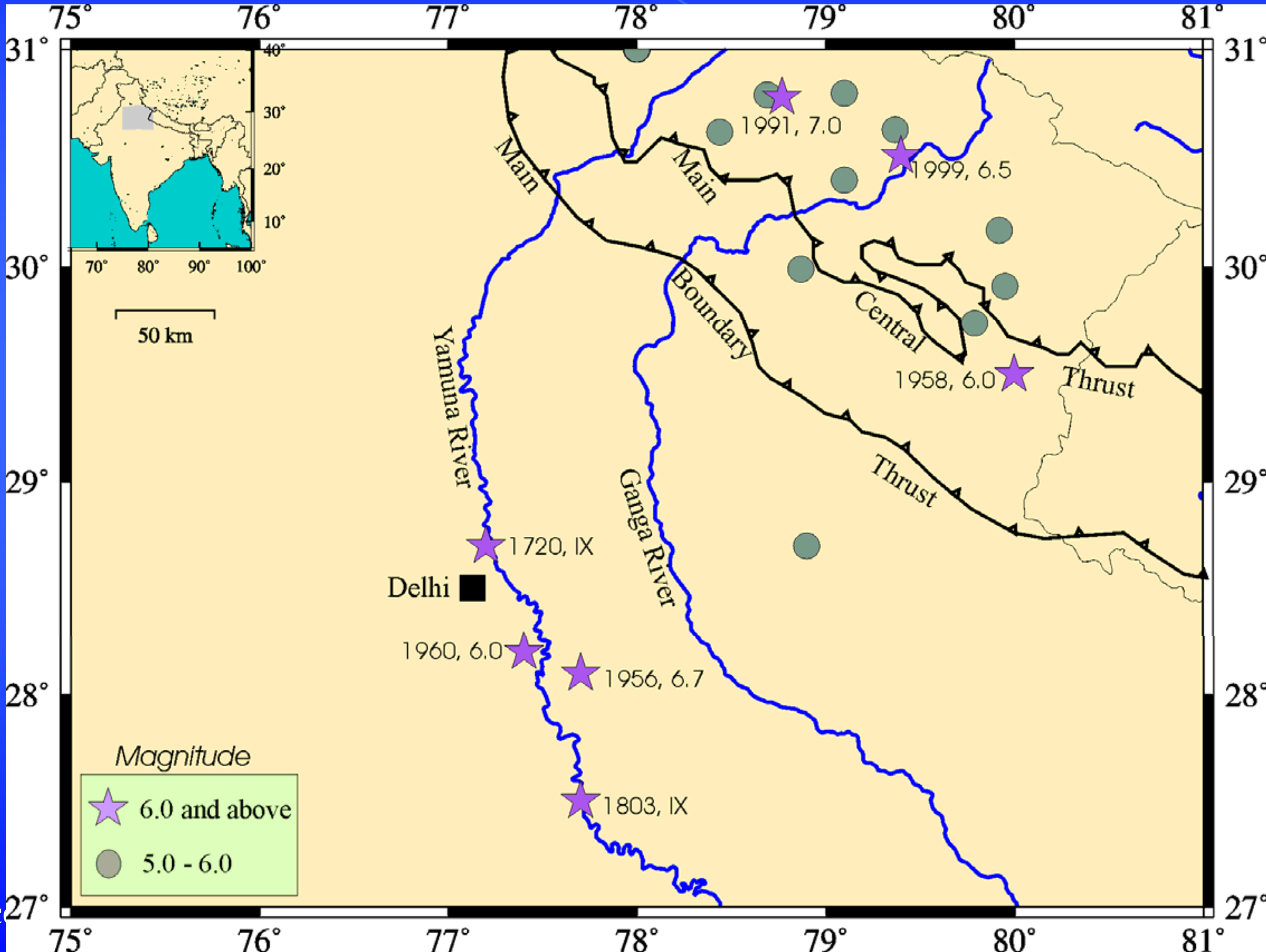
Site-specific ground motion modelling for microzonation studies is still under progress in India. Few studies are already underway towards the microzonation of Delhi, Sikkim Himalayas, Jabalpur, Guwahati etc. But, still many more megacities and urban areas which are under seismic threats need to be addressed for site-effect studies.

There are few research work being done in this direction

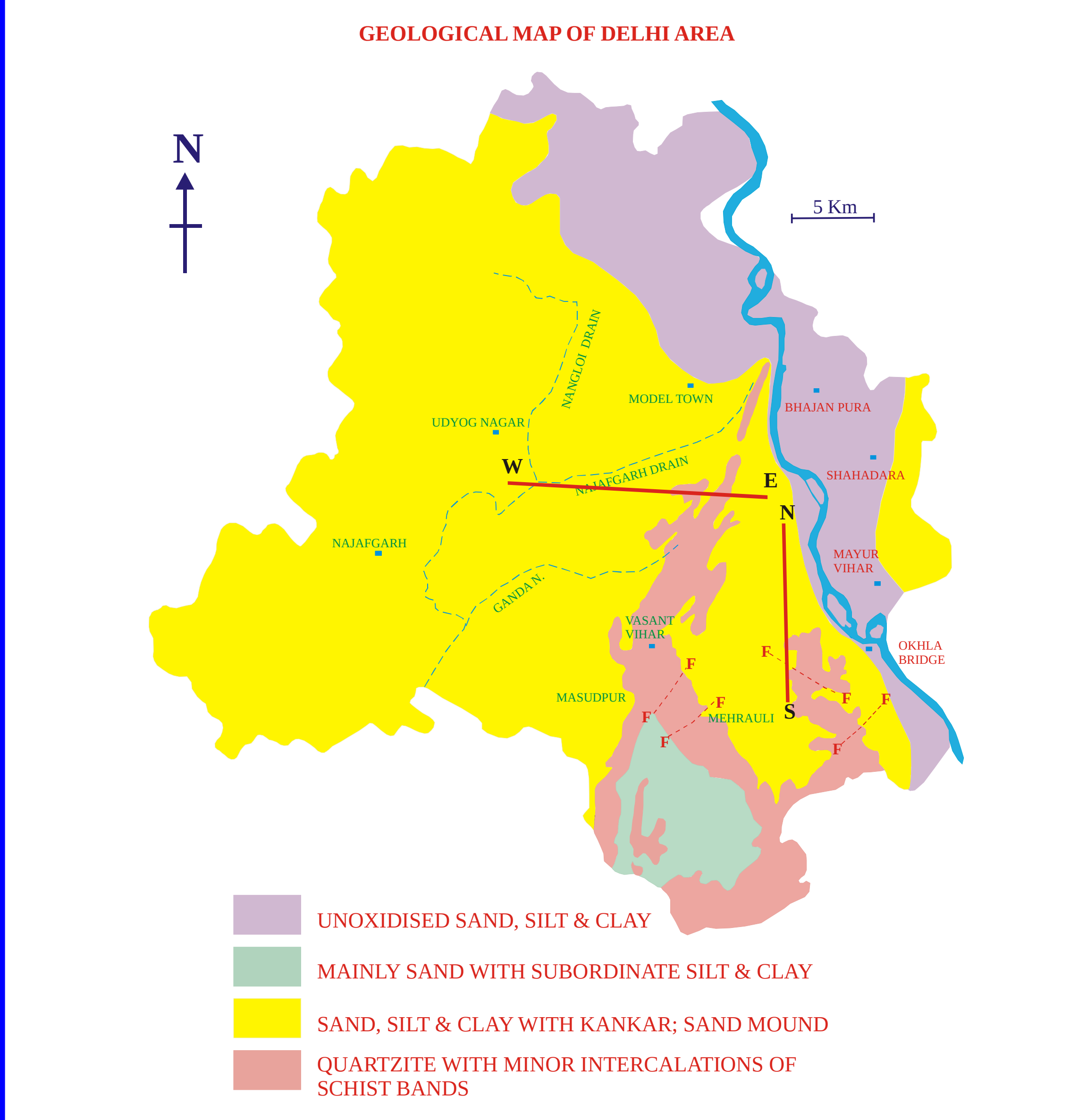
1. **Nath et al., 2000. — Sikkim Himlayas**
2. **Parvez et al., 2002, 2004, 2006 — Delhi**
3. **Mukhopadhyay et al., 2002 — Delhi**

Site-specific ground motion modelling in Delhi

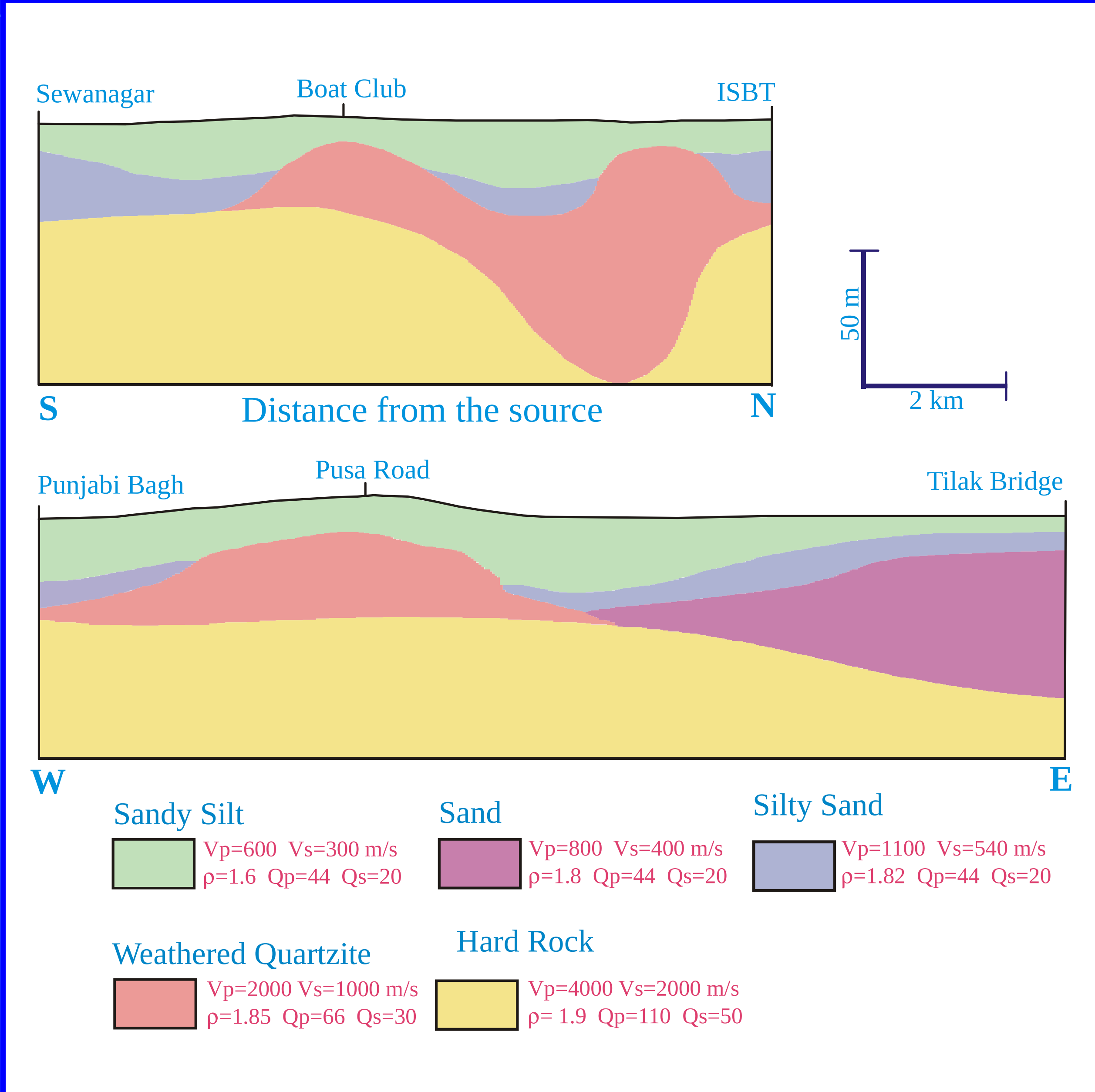
Parvez et al., 2002, 2004



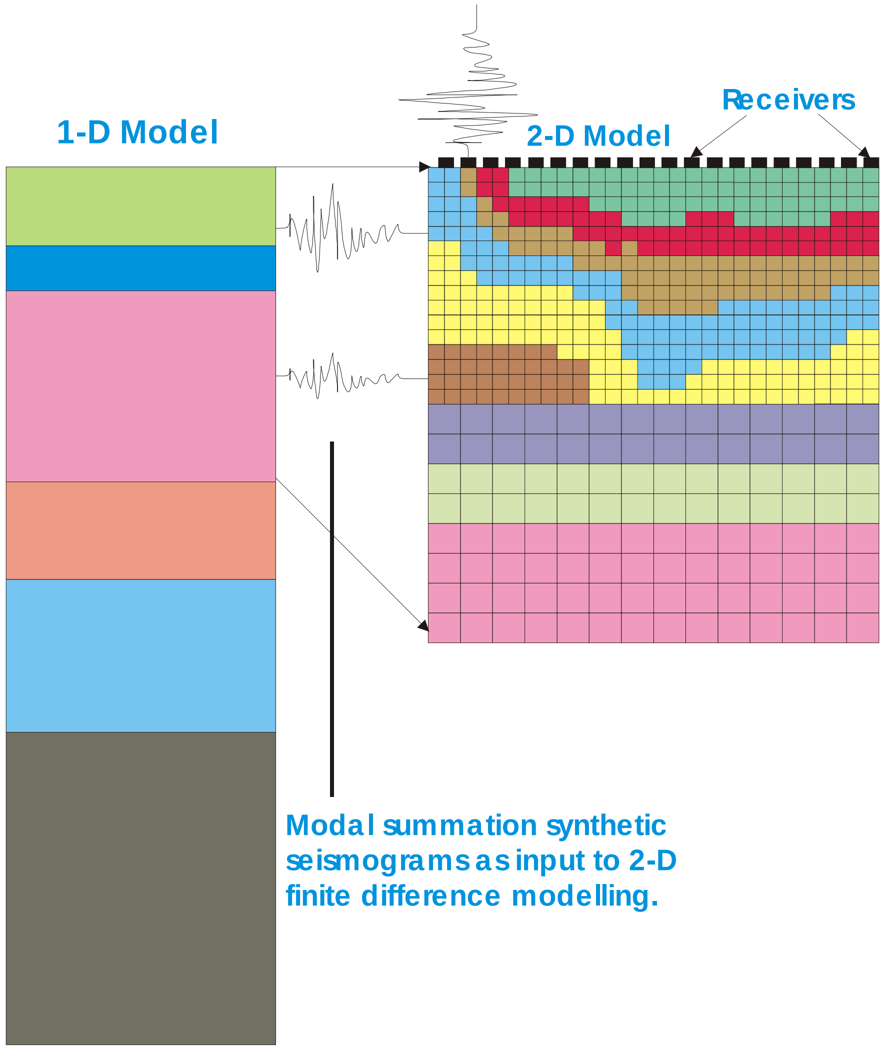
Geological Map of Delhi and the two cross-sections NS and EW along which the computations were done.

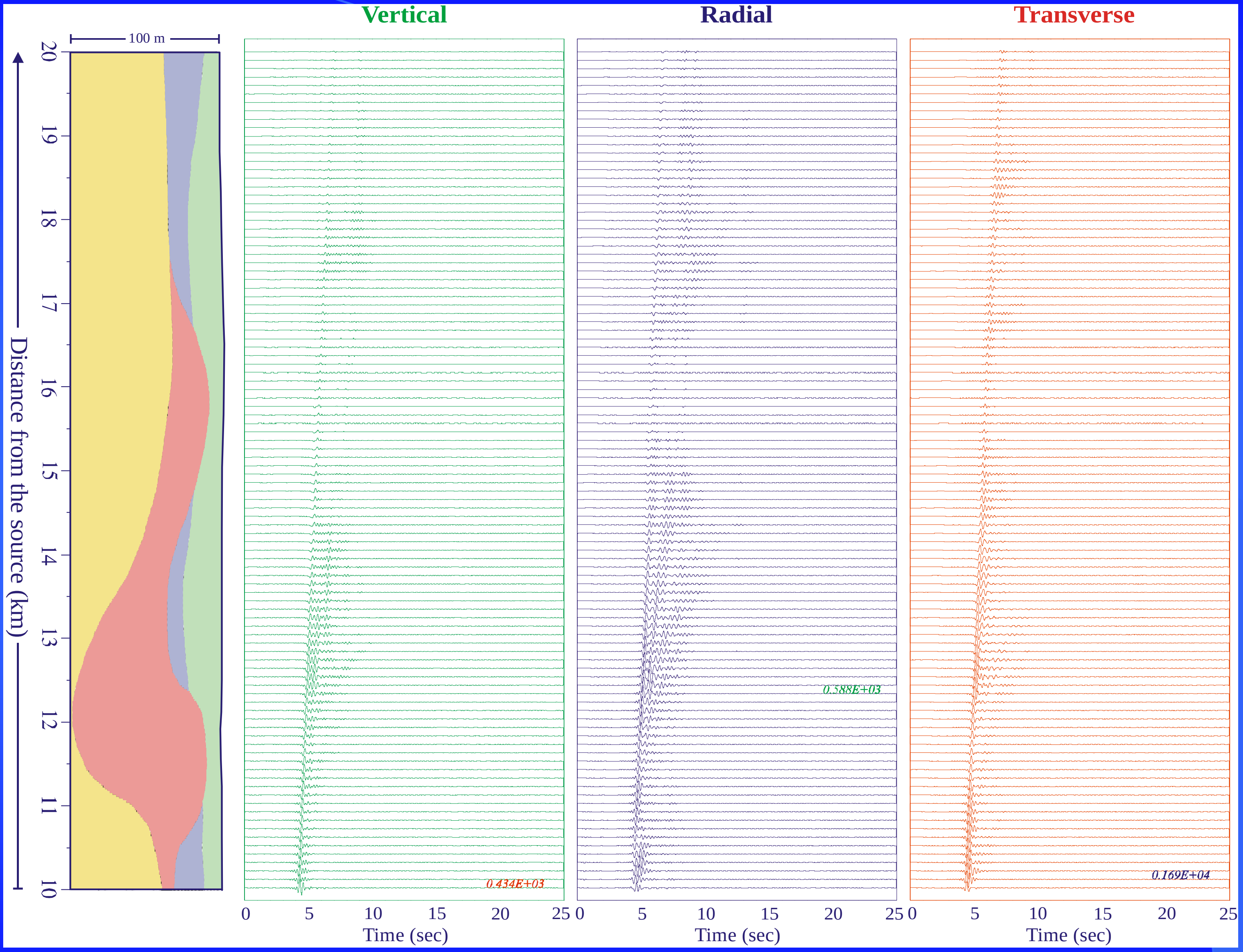


Sub-surface structural parameters used for the study. The profiles are taken from Iyengar (2000).



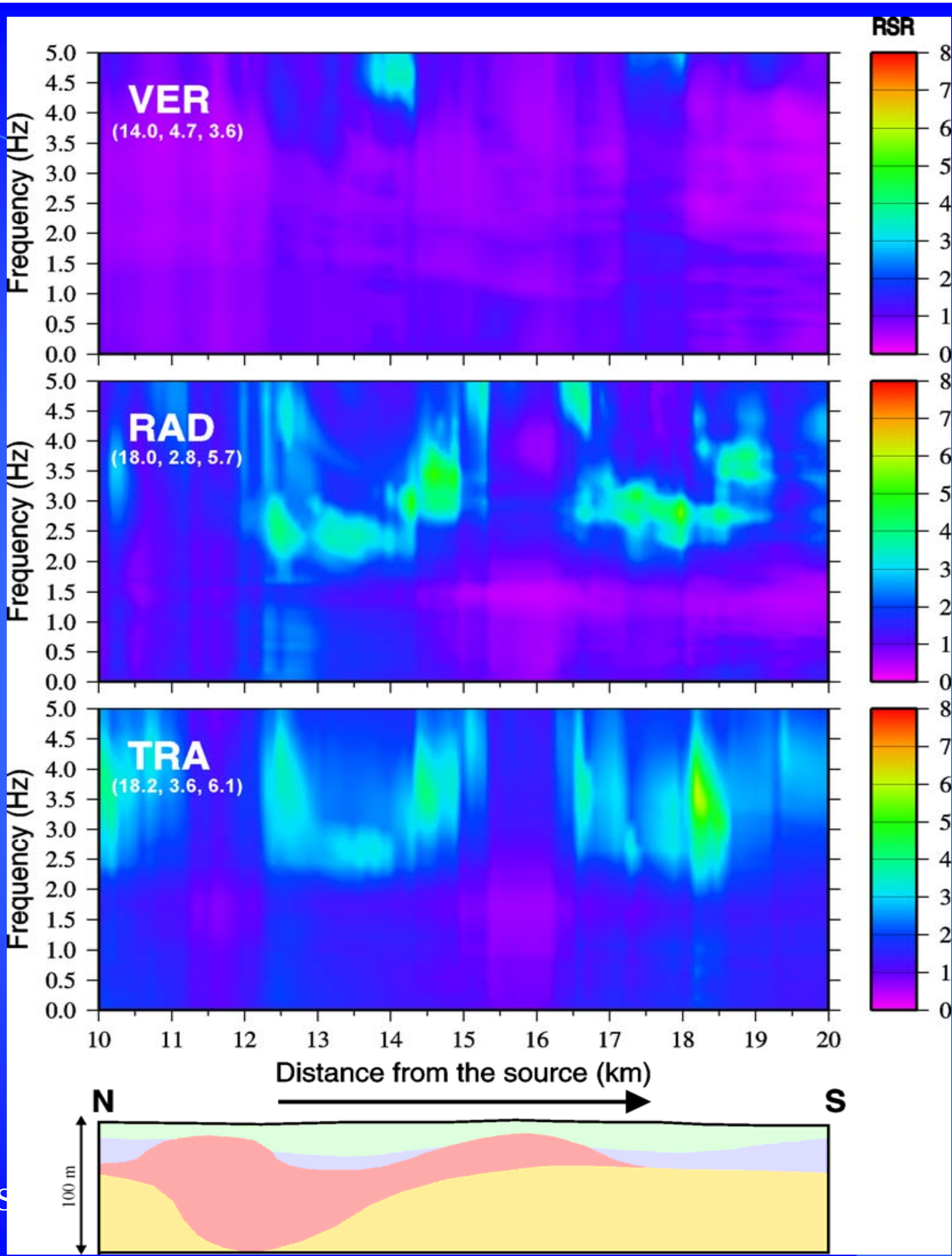
Schematic representation of the hybrid technique

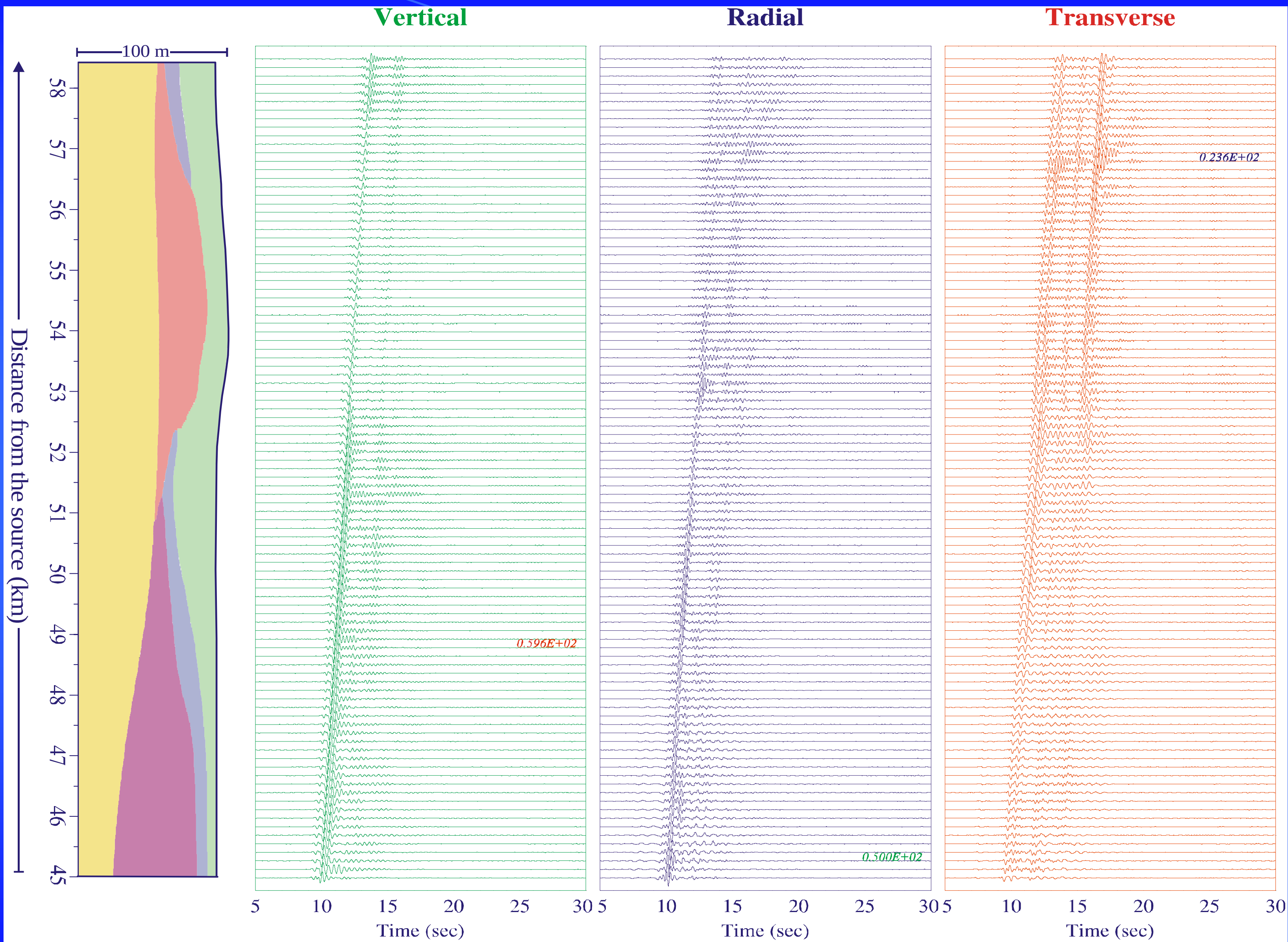




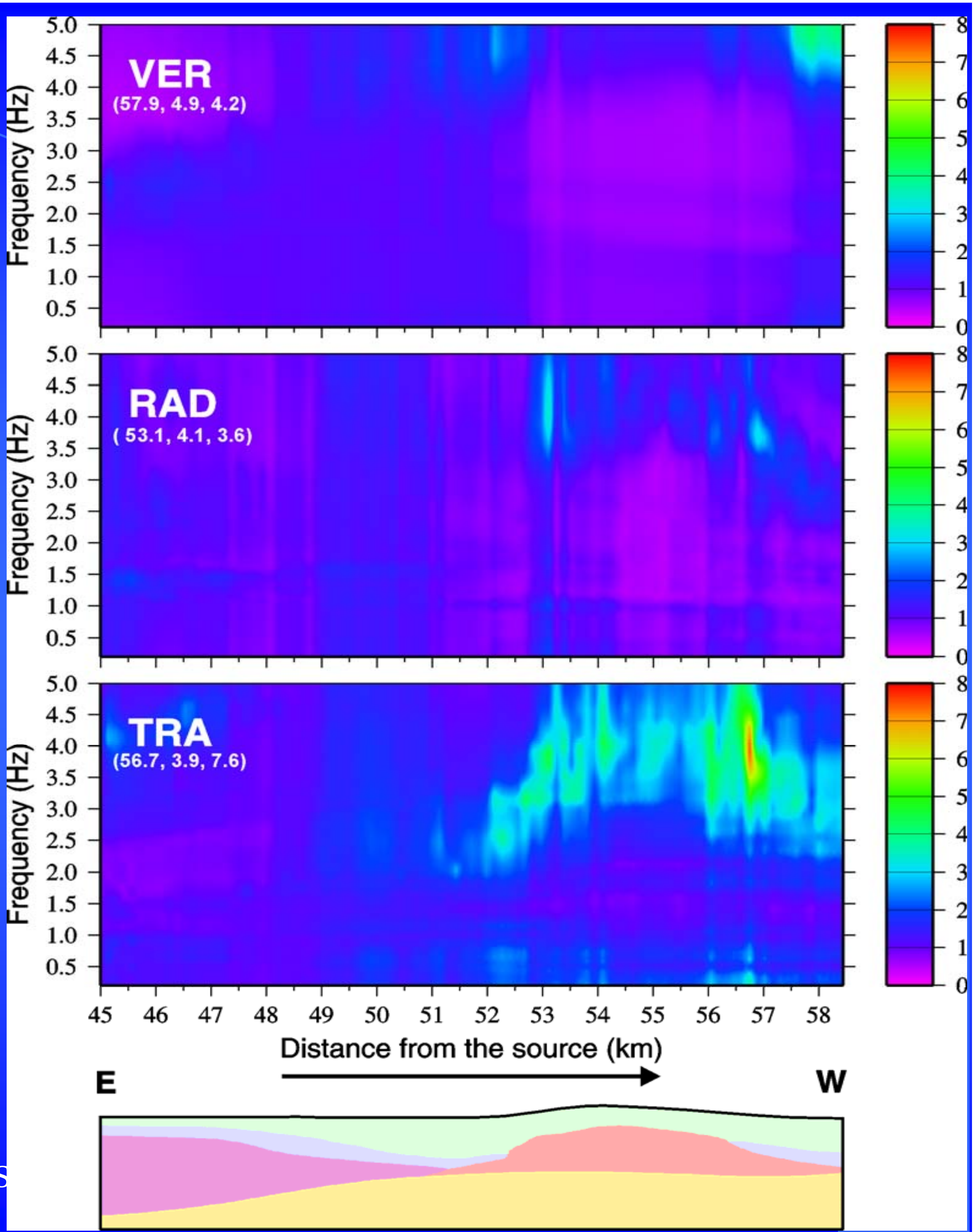
Vertical
Radial
Transverse
100 m
Distance from the source (km)
20
19
18
17
16
15
14
13
12
11
10
0.434E+03
0.588E+03
0.169E+04
0 5 10 15 20 25
Time (sec)

The amplification and frequency plotted together along the NS profile for all the three components.



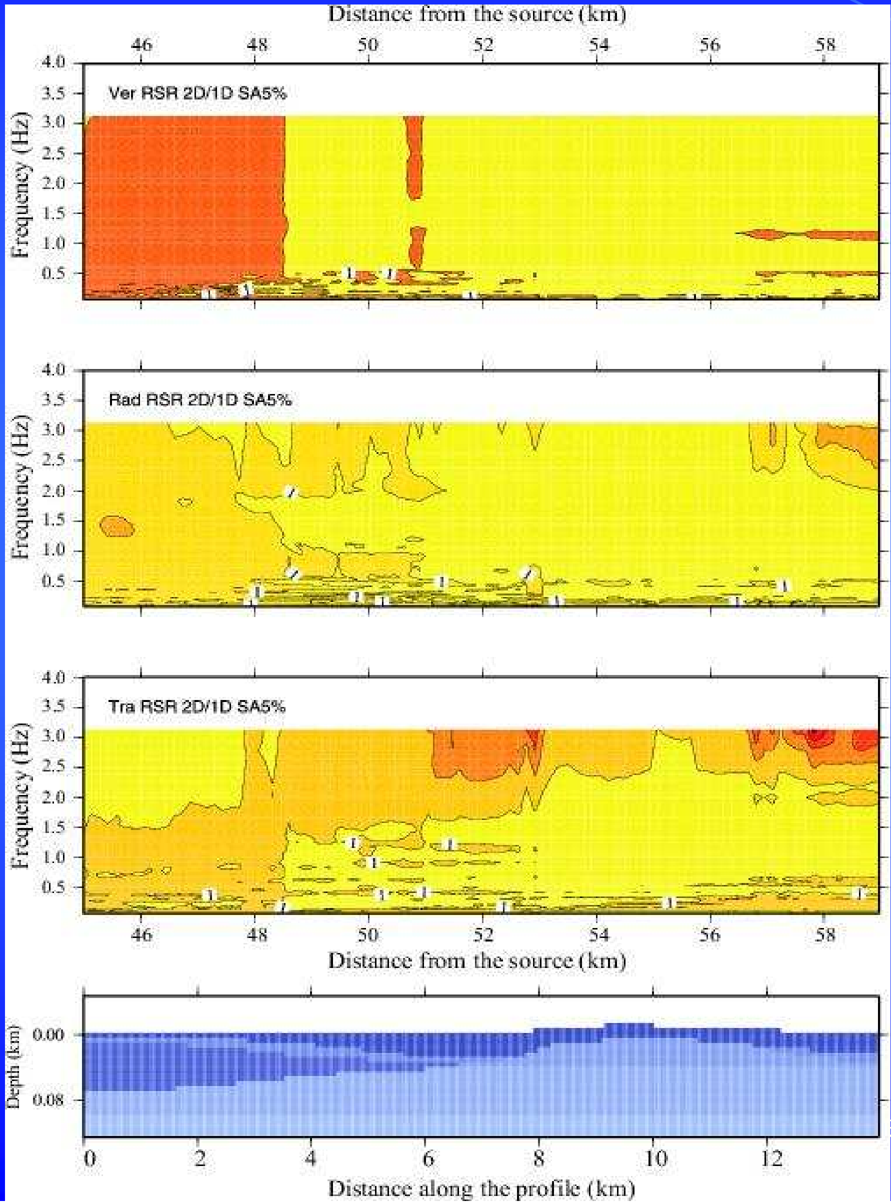

Vertical
Radial
Transverse
100 m
Distance from the source (km)
58
57
56
55
54
53
52
51
50
49
48
47
46
45
0.596E+02
0.300E+02
0.236E+02
5
10
15
20
25
30
Time (sec)

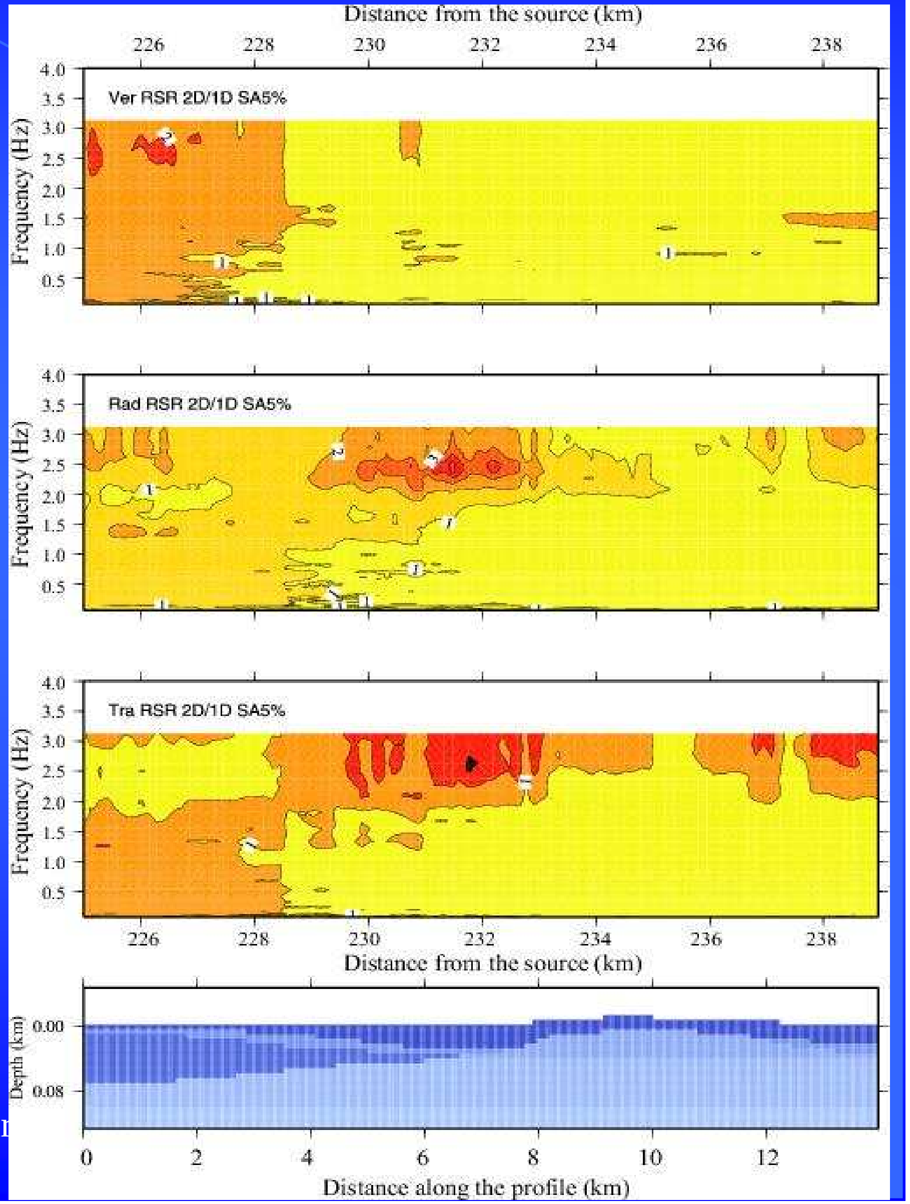
The amplification and frequency plotted together along the EW profile for all the three components.



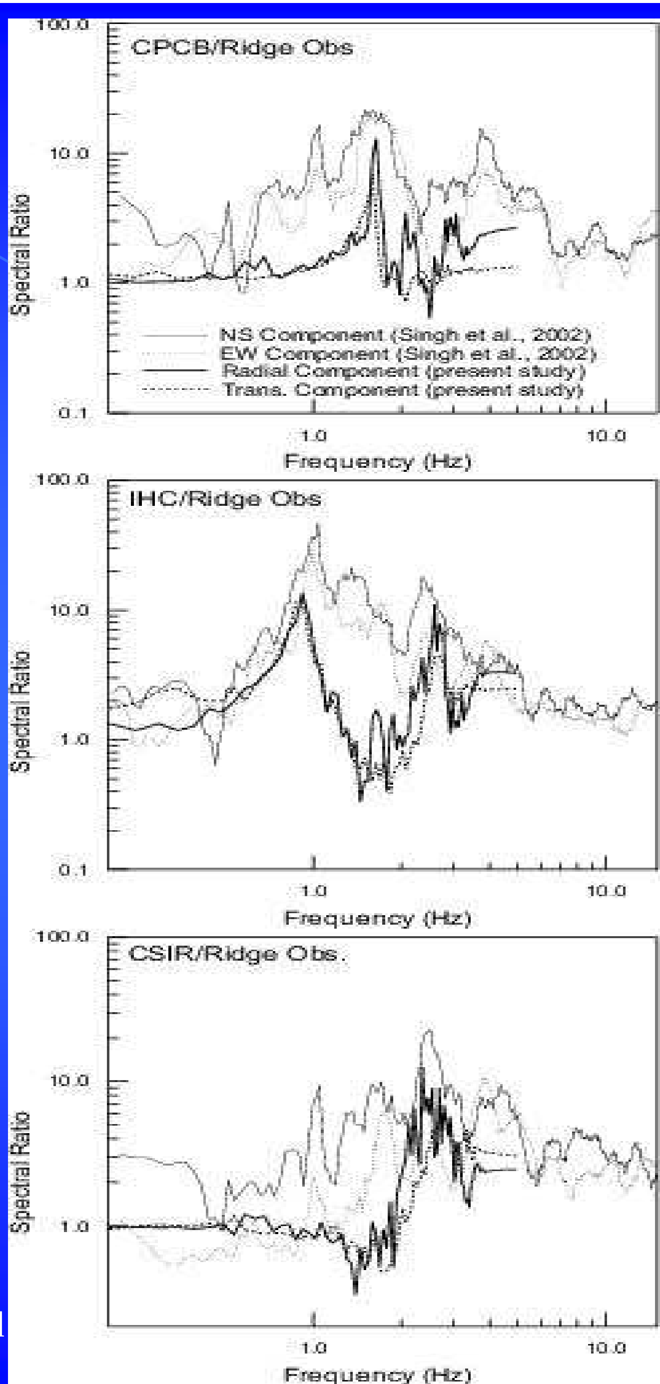
Influence of source distance on site-effects

Parvez et al., 2006, Curr. Sc.



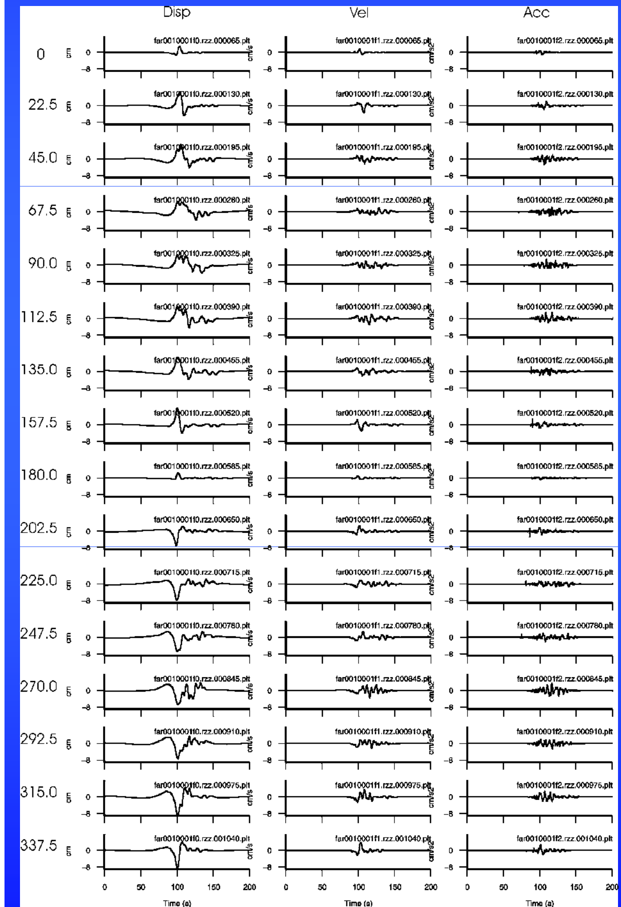


Comparison of spectral ratios of simulated and observed records at three sites in Delhi.

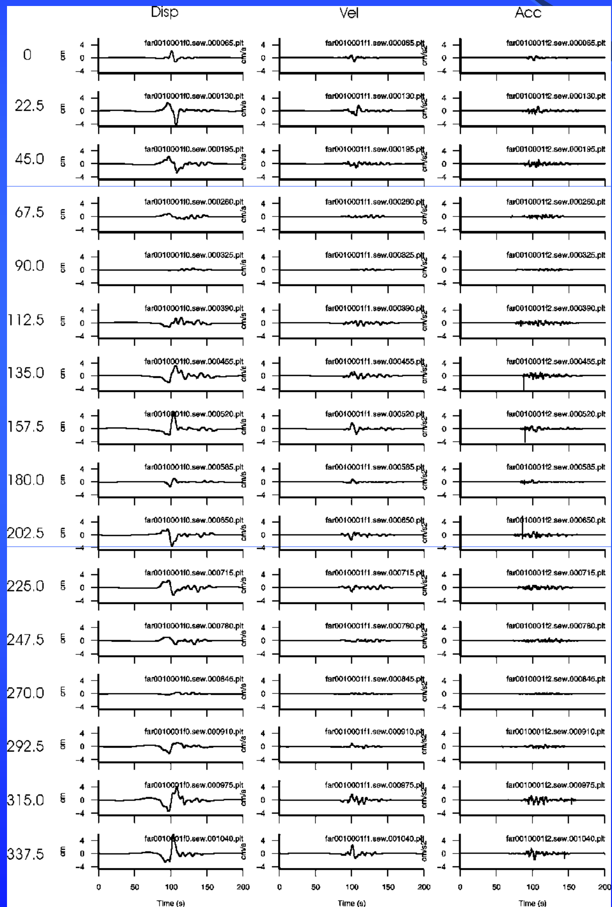


The bedrock level ground motion simulated in Delhi city using a scenario earthquake in central Himalaya using extended source; the parametric tests by changing the strike-receiver angle.

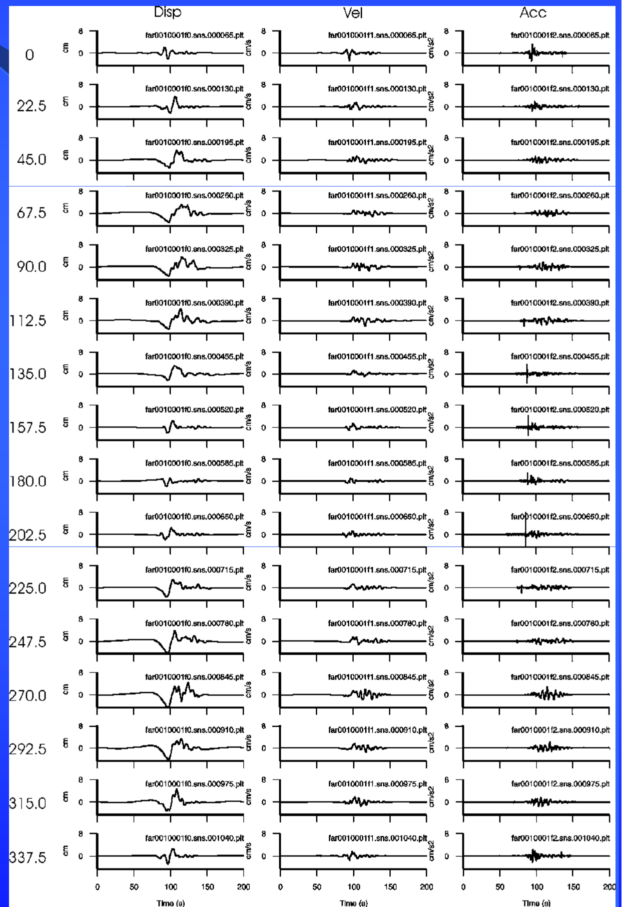
Vertical



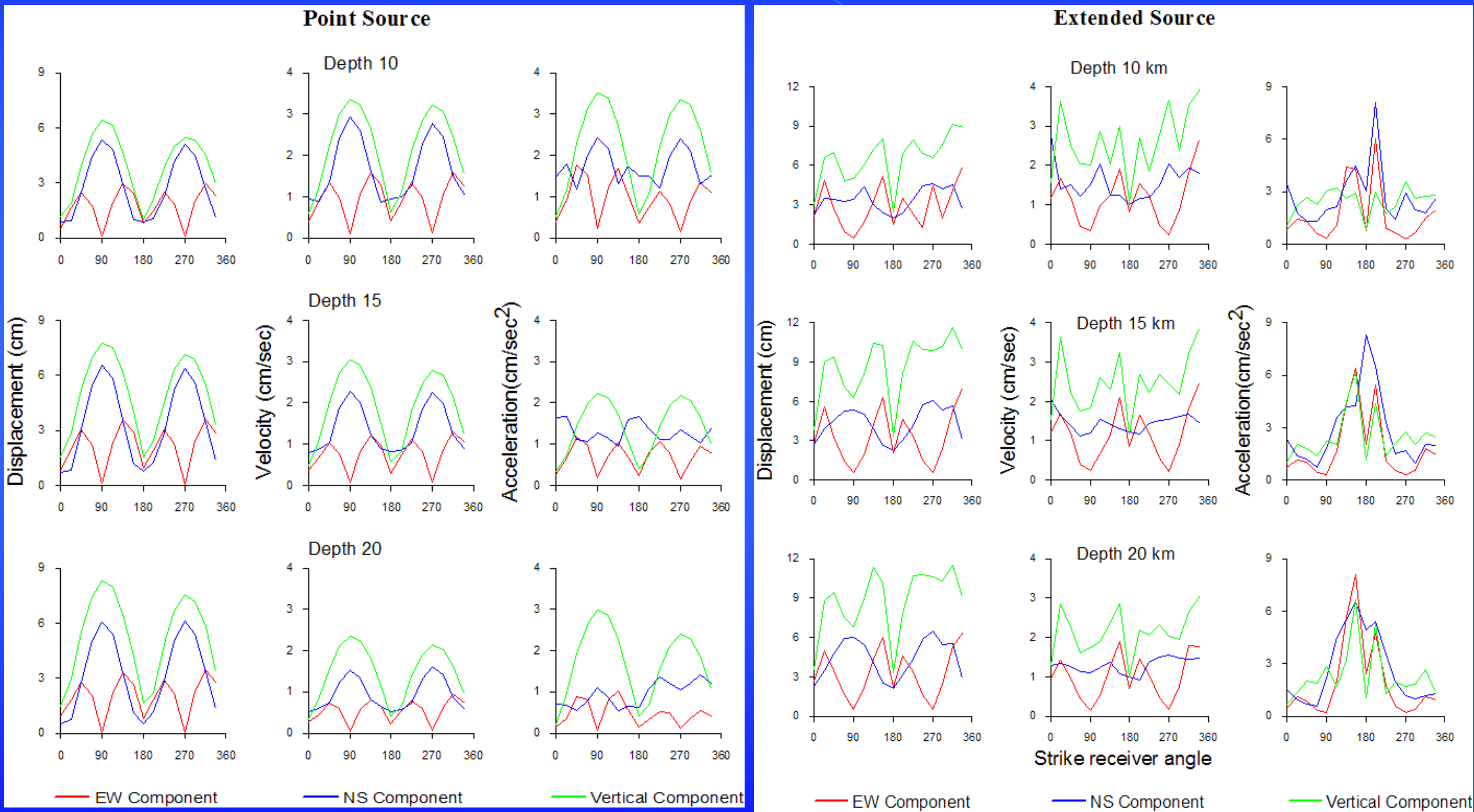
East-West



North-South



Peak values ~ strike receiver angle



Conclusions

Not yet concluded !!

It's Going On ....

Thanks a Lot