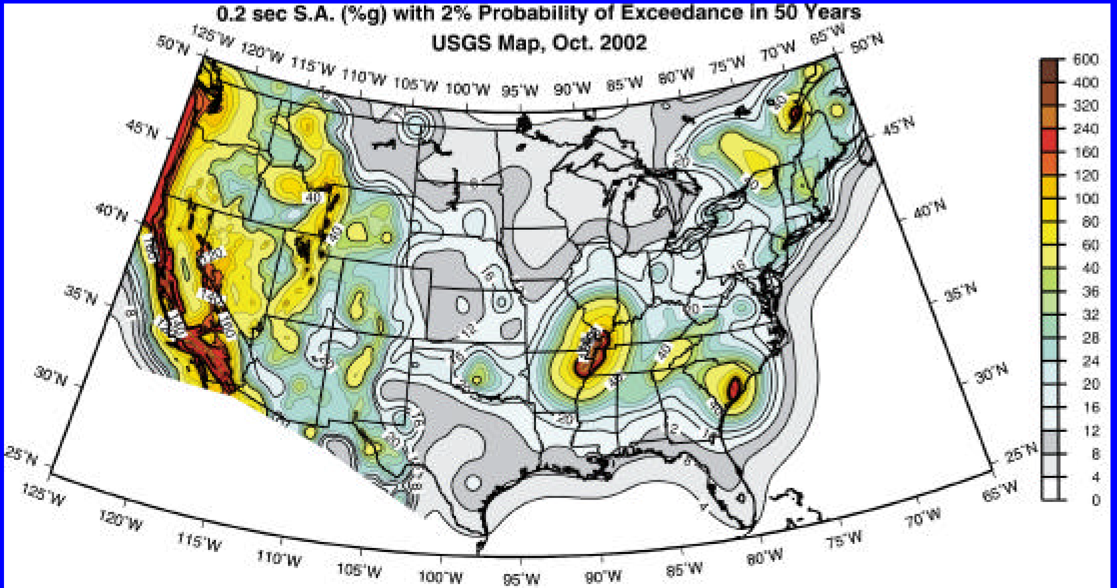
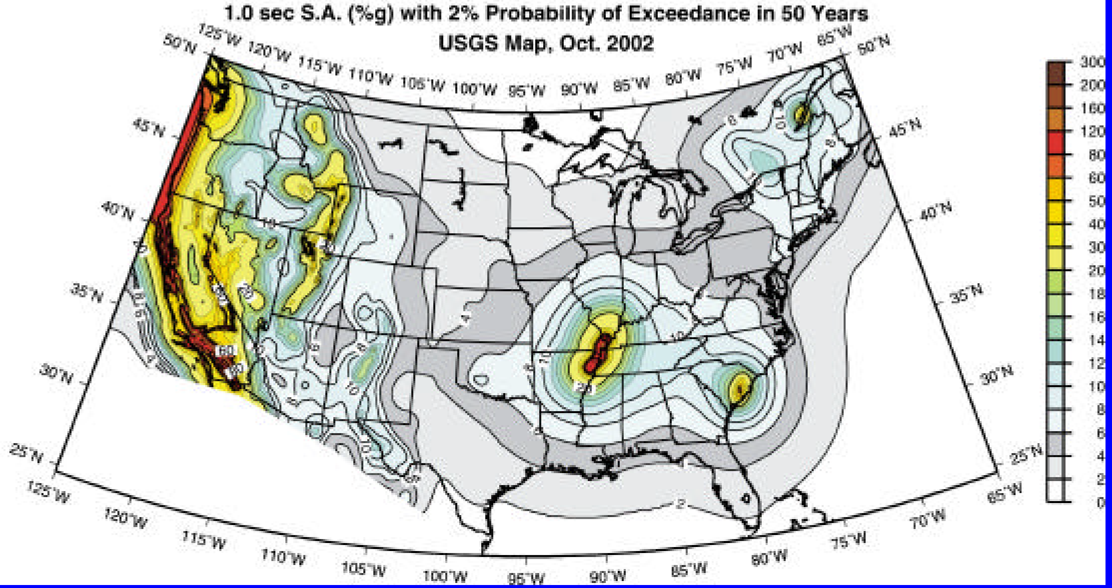
Challenges in Hazard Estimation: Examples from the U.S. National Seismic Hazard Map

Mark Petersen, Arthur Frankel, Robert Wesson,Charles Mueller,
Stephan Harmsen, and David Perkins

Earthquake Hazards Reduction
Program





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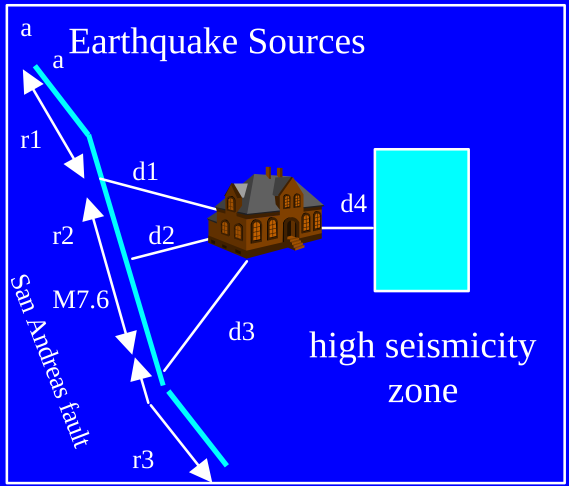
National Seismic Hazard Maps: 2002 Update

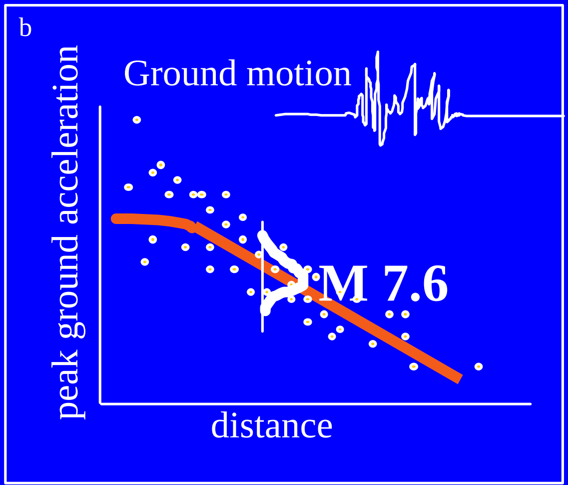
- We held 4 regional workshops + ATC workshop on user needs + co-convened GPS workshop
- Continued collaboration with CA Geological Survey
- Draft updates of maps released in Jan. for review and comment. See geohazards.cr.usgs.gov/eq/
- New fault parameters were reviewed by western state geological surveys. External panel is also reviewing maps.
- Second round of draft maps released end of August. Final maps in early October.
- We are working with BSSC for incorporation of new maps into future NEHRP Provisions

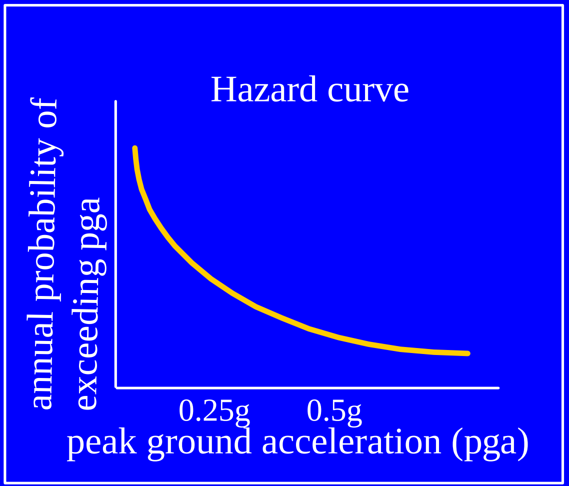
Some Major Uses of the National Seismic Hazard Maps and Associated Products

- Building codes: International Building Code, International Residential Code, ASCE national design load standard, NEHRP Provisions
- Design of highway bridges, dams, landfills
- Loss estimation (e.g., HAZUS), earthquake insurance
- Emergency management, EQ scenarios

Hazard Methodology Example



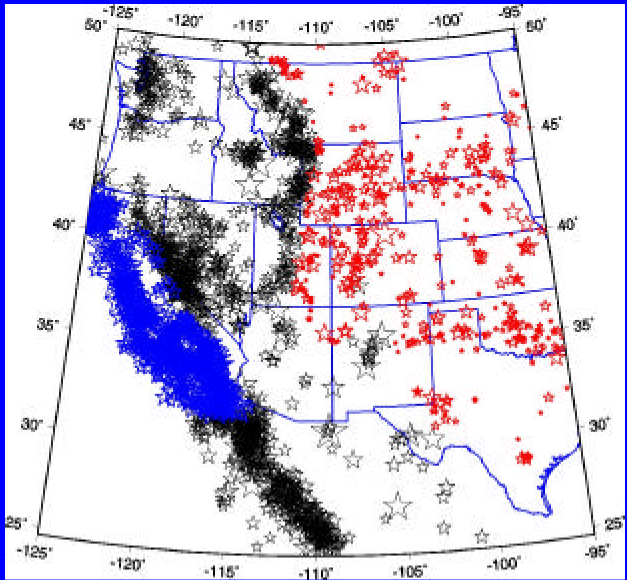




Direct Inputs to Hazard Maps

- Earthquake catalogs (instrumental and historic)
- Fault data (geologic slip rates, dates of past events from trenching, fault geometry, etc.)
- Effects of prehistoric earthquakes: paleoliquefaction (New Madrid, Charleston, Wabash Valley), subsidence and uplift (Cascadia, Seattle flt)
- Geodetic data (NV-CA, Puget Lowland)
- Ground-motion attenuation relations

Earthquakes Used in Hazard Maps



Red: M >= 3.0

Blue and Black: M >= 4.0

(colors indicate different completeness times)

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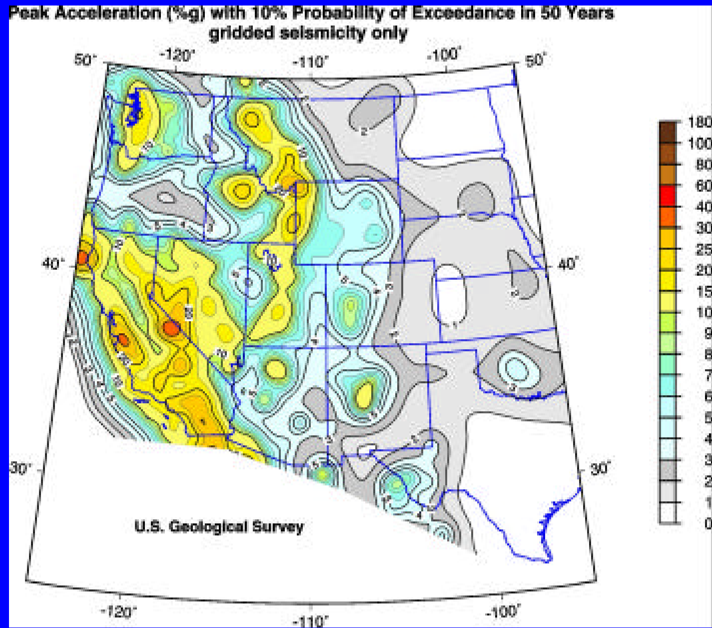

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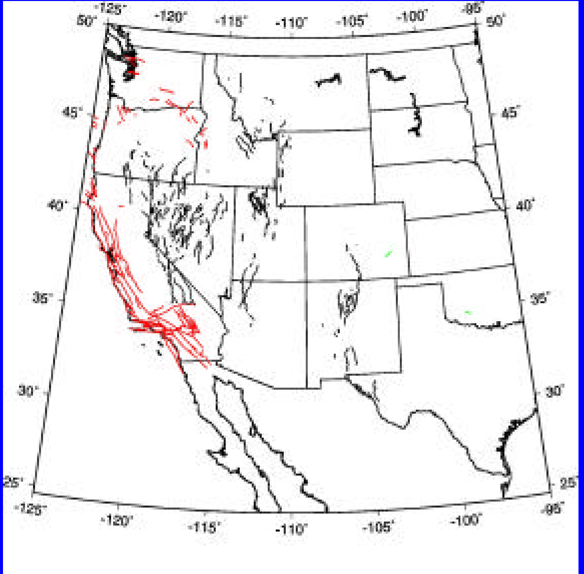
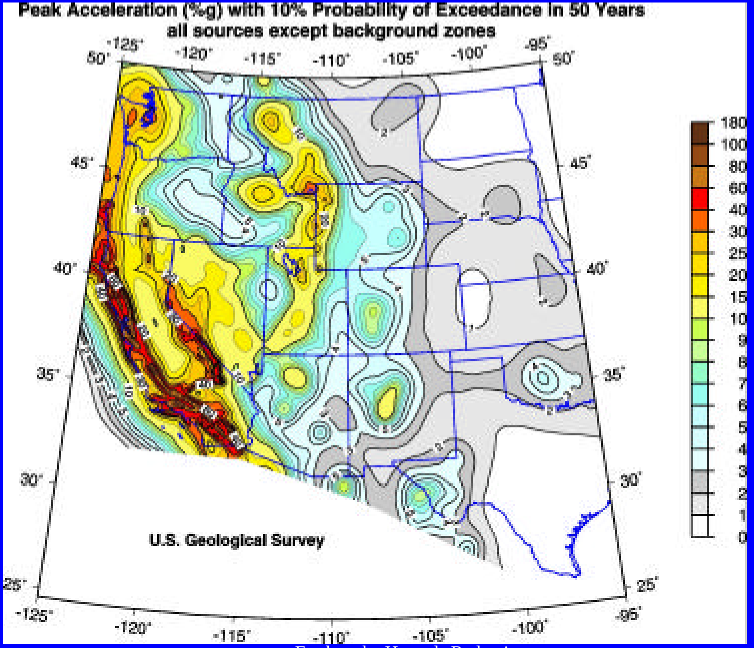


Fig 4. Faults used in 2002 maps, color coded based on the set of ground-motion attenuation relations used to calculate their hazard. Black traces are faults in extensional areas, red traces are faults in non-extensional areas. Green traces are faults in CEUS attenuation area.



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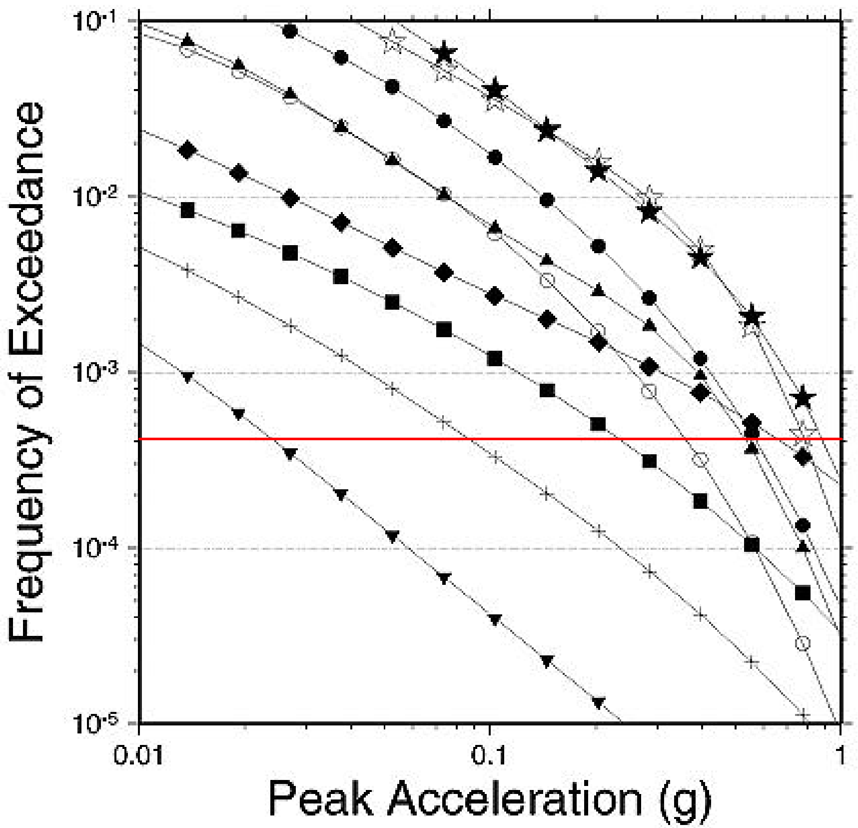


Line shows 2% Prob. of Exceedance in 50 year; Approx. 2500 yr return time

Challenges:

1. Modeling fault geometry (e.g., blind thrusts, seismogenic rupture dimensions)
2. Understanding sizes of earthquakes on each source
3. Modeling earthquake recurrence using slip rate (e.g., characteristic model, GR model)
4. Modeling time-dependence (understanding shape of recurrence distribution and the associated uncertainty)
5. Modeling ground motion (directivity, basin effects, motion in different directions)
6. Communicating hazard (engineers and public)

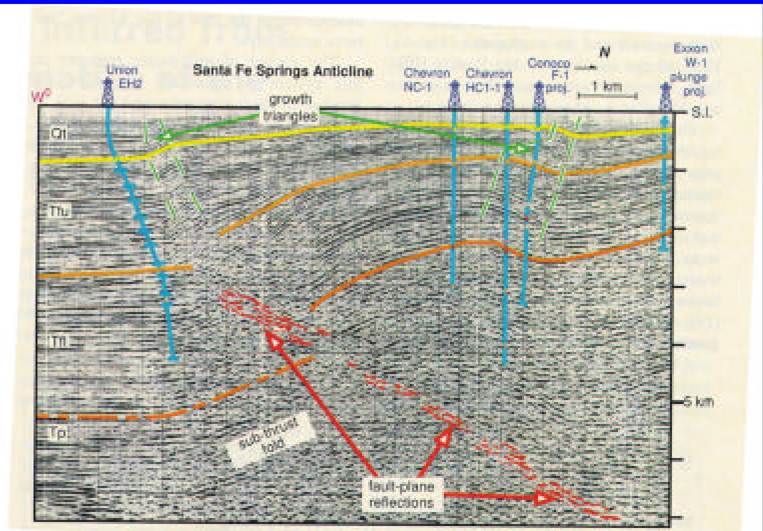
Modeling fault geometry

Blind thrusts

Subduction zones

Shaw and Shearer, 1999

Blind-thrust fault
Beneath Los
Angeles



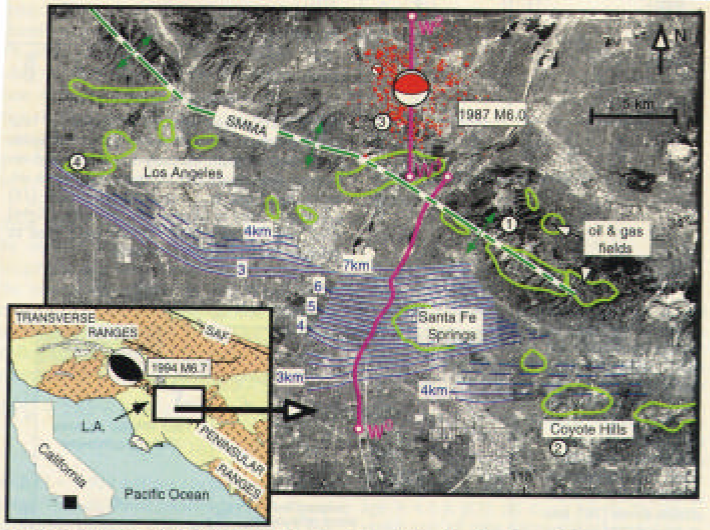
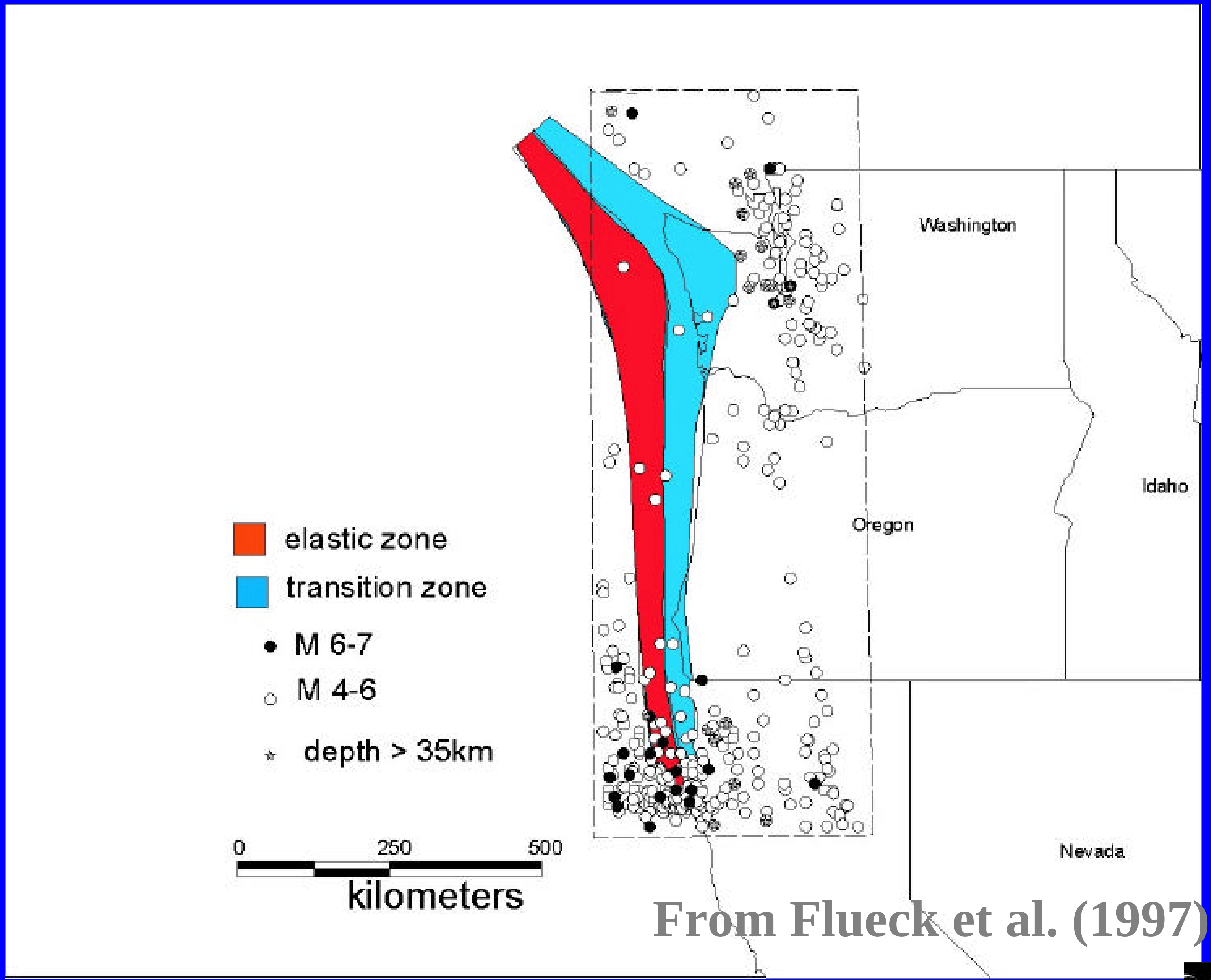


Fig. 2. Contour map of the Puente Hills thrust system with revised locations of the 1987 Whittier Narrows (*M* 6.0) earthquake and aftershocks. The map is overlain on a LandsatTM image (band 5). The inset shows the location of the 1994 Northridge (*M* 6.7) earthquake. SMMA, Santa Monica Mountains anticlinorium (5); SAF, San Andreas fault. SCSN seismograph stations: 1, TCC; 2, FLA; 3, GVR; and 4, SC1. Green curves denote locations of oil and gas fields. W^0-W^1 and W^1-W^2 are traces of sections shown in Figs. 1 and 4.

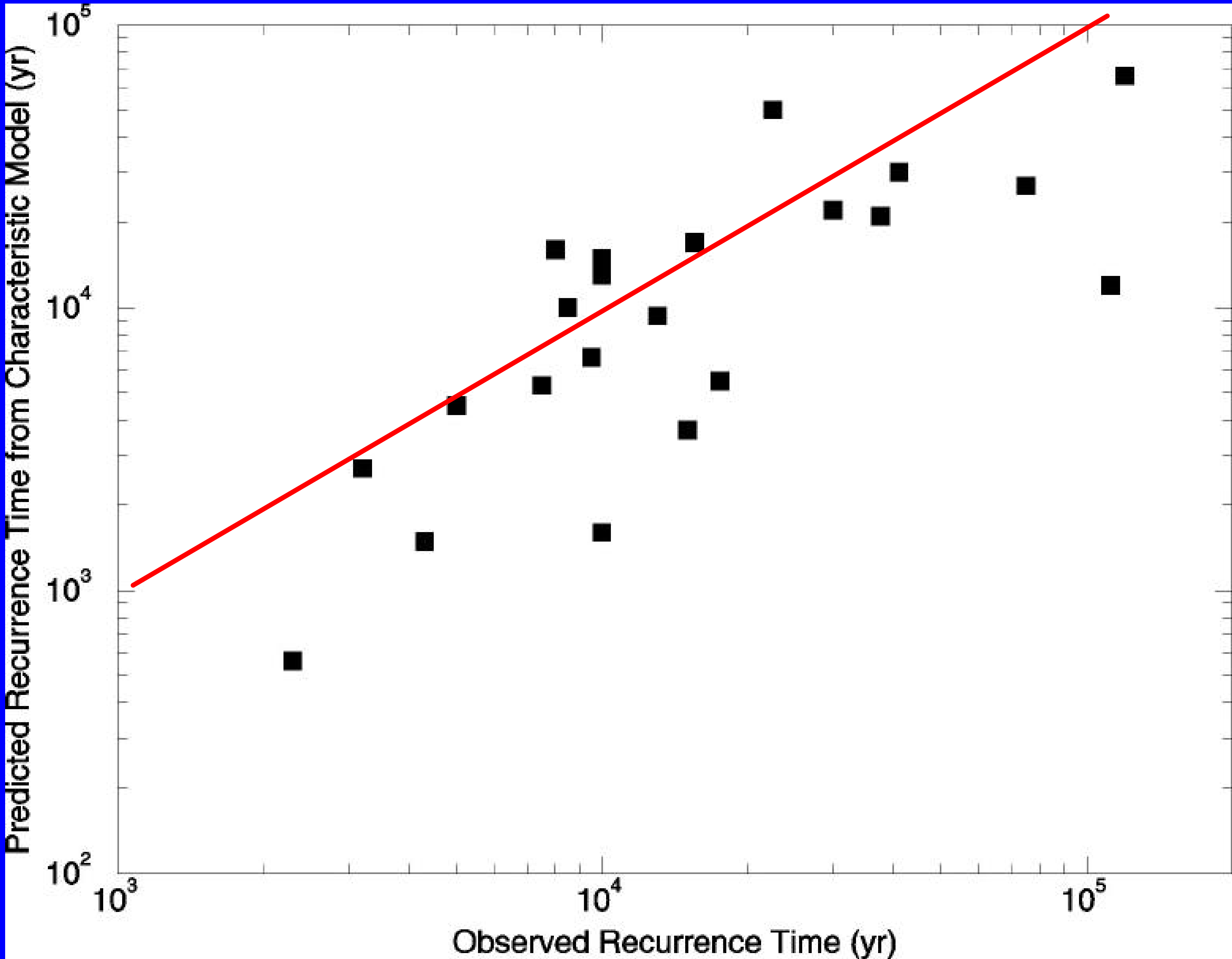
Possible configurations for rupture zone of great Cascadia Earthquakes



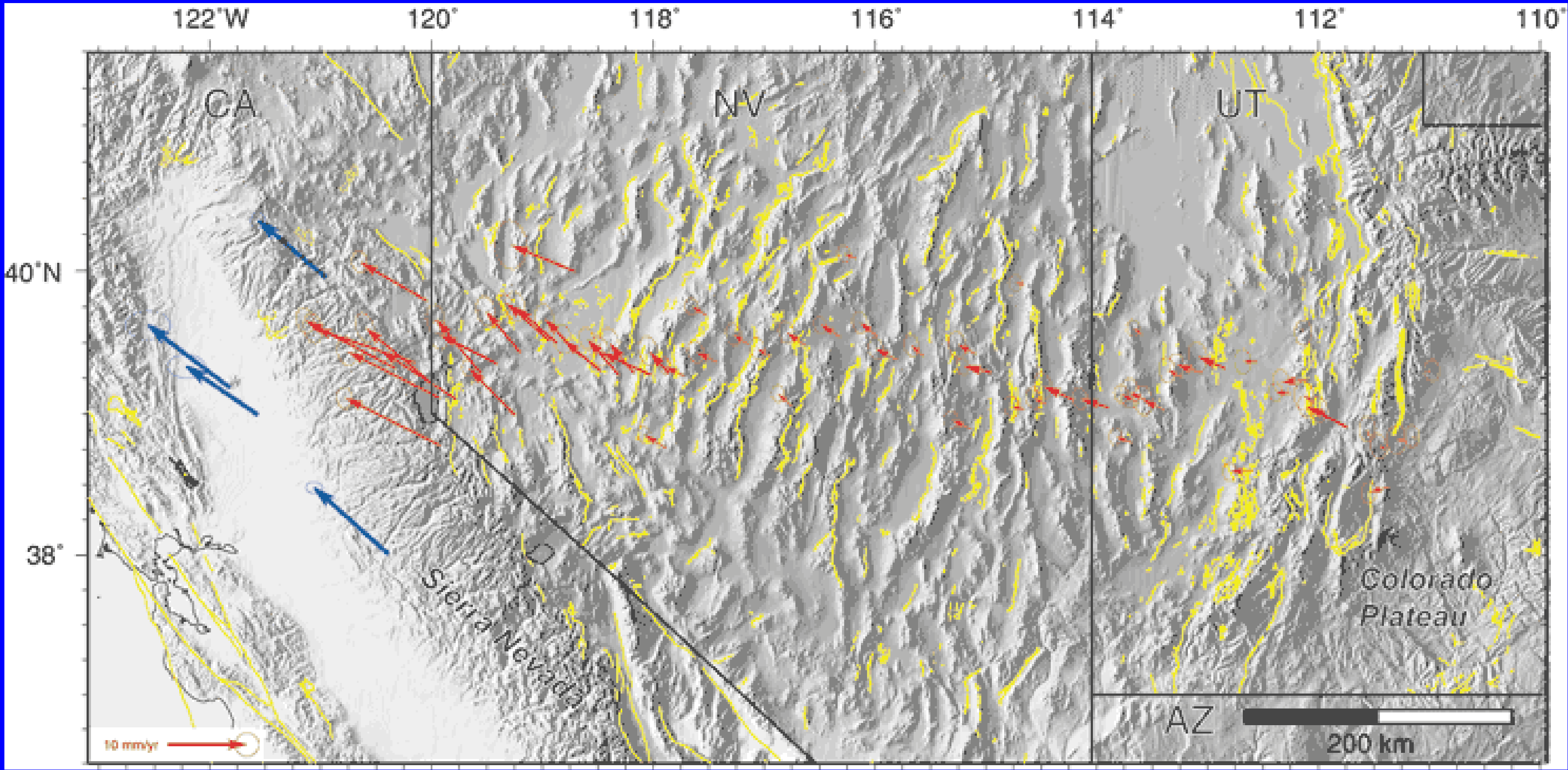
Modeling earthquake recurrence

Slip rates
Paleoseismic
GPS
Time-dependence

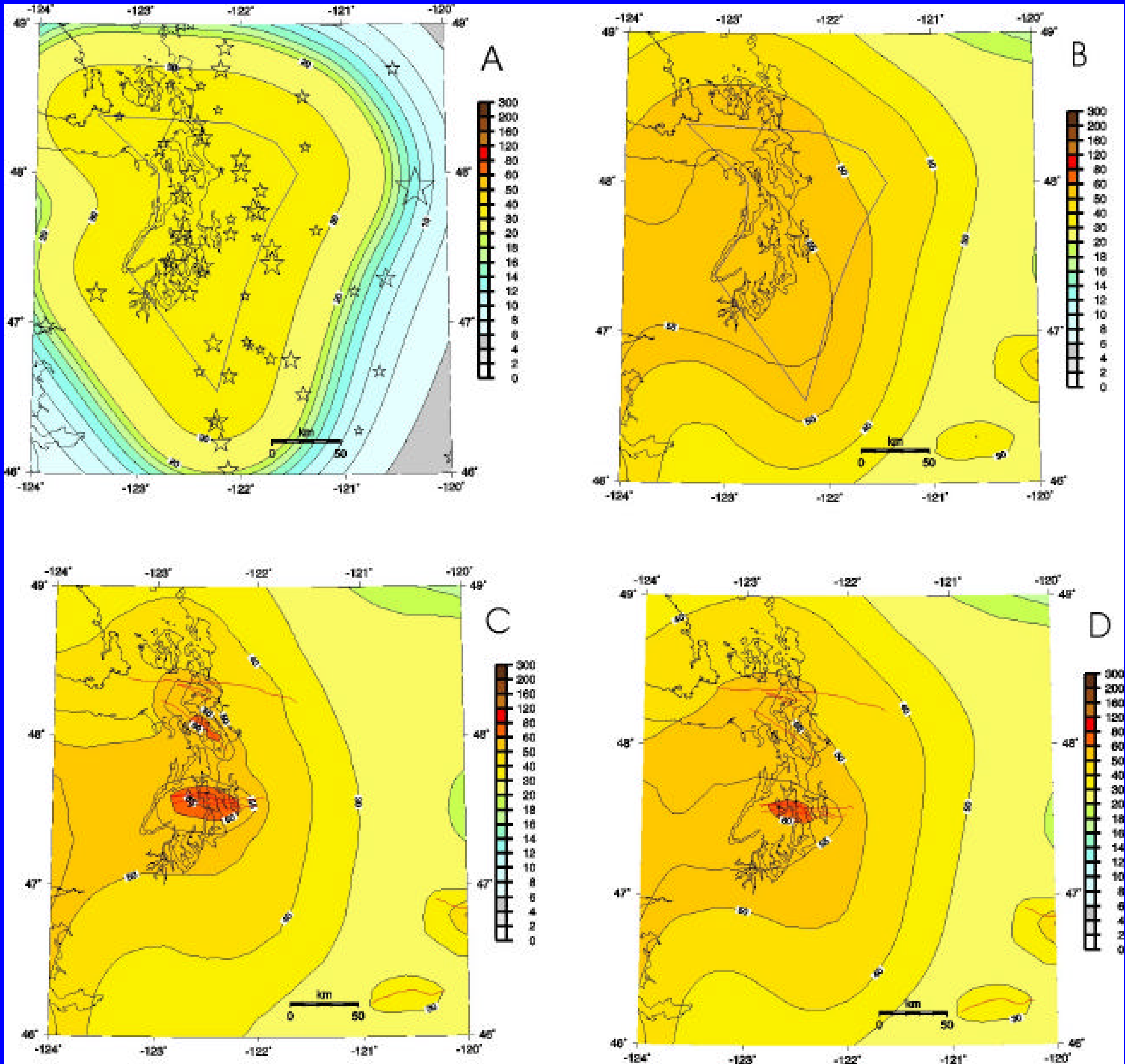
Recurrence from long-term slip rate of fault



Recurrence from geodetic data

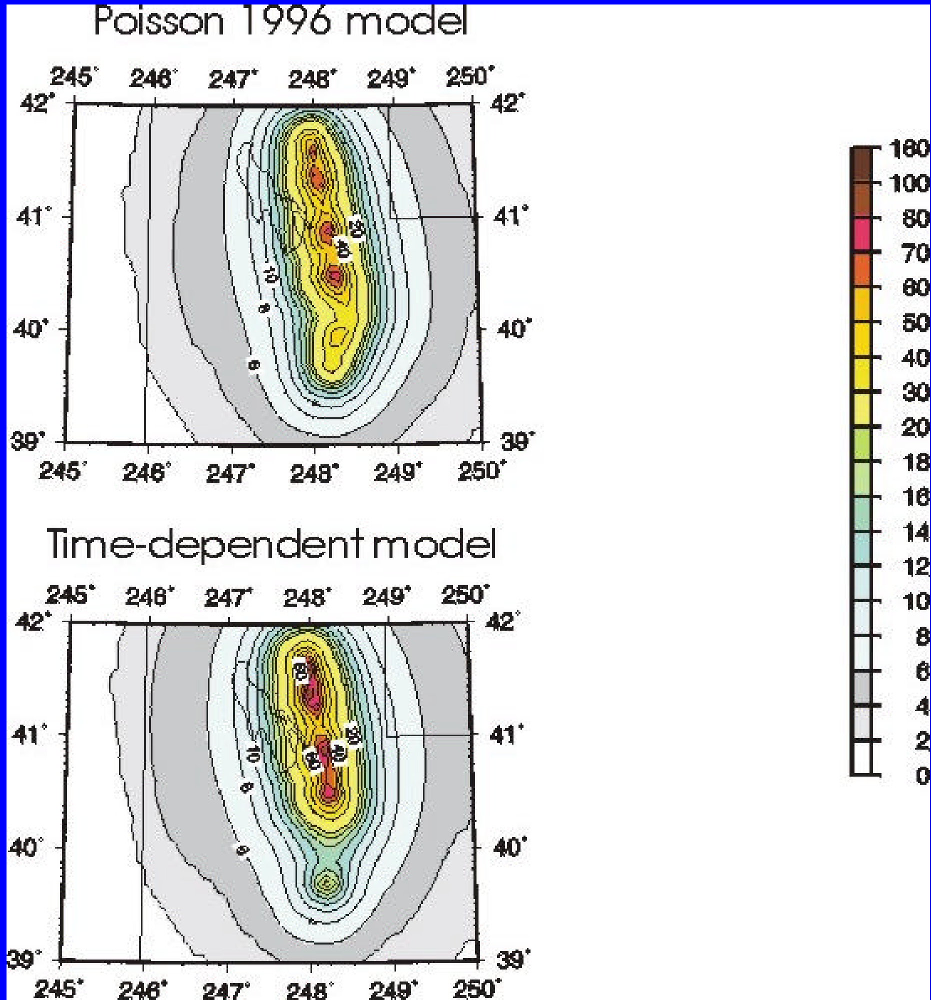


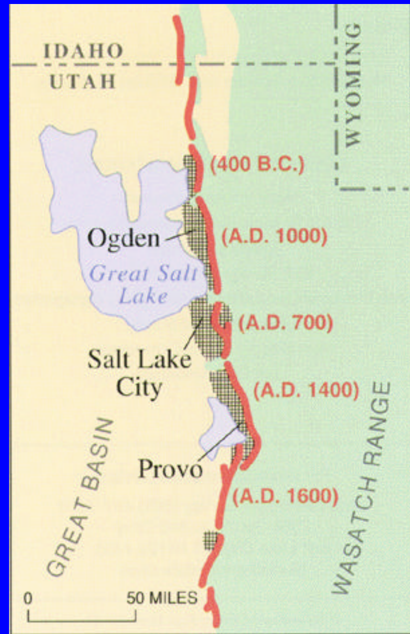
From Thatcher et al. (1999)



Incorporating GPS measurements of deformation into hazard maps

Time-dependent hazard maps





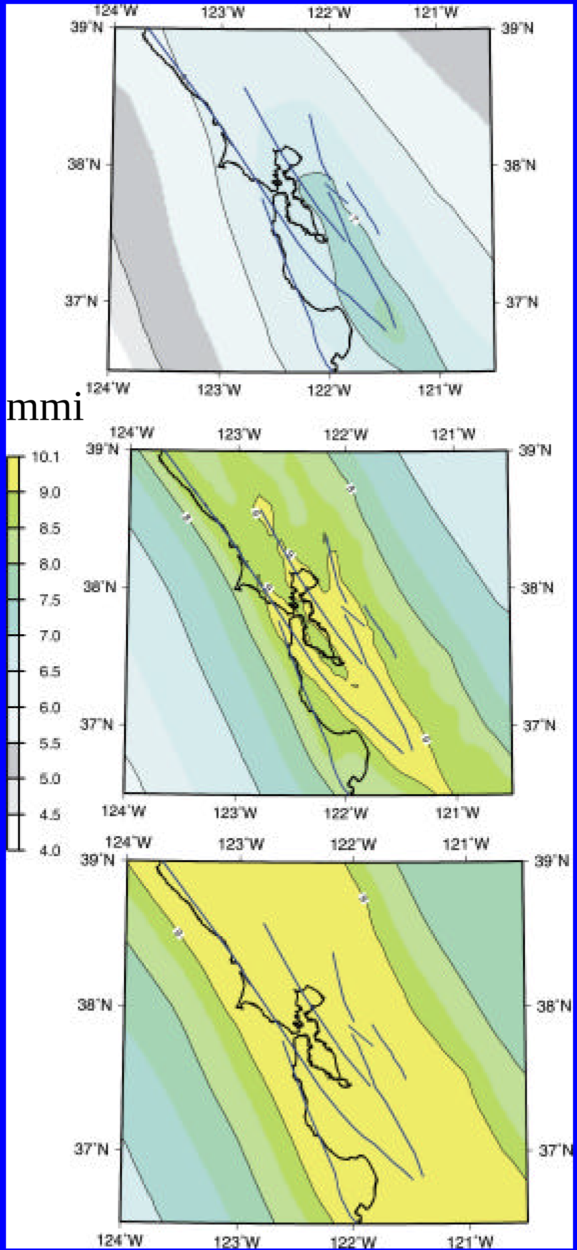
	Med. Rec.	Elapsed time	50-year prob	
Brigham City:	1230	2175	8%	4%
Weber:	1674	1066	3%	3%
Salt Lake:	1367	1280	6%	4%
Provo:	2413	668	0.1%	2%
Nephi:	2706	1198	0.8%	2%

Communicating Risk: using Intensity

70 year

500 year

2500 year



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Modeling ground motion

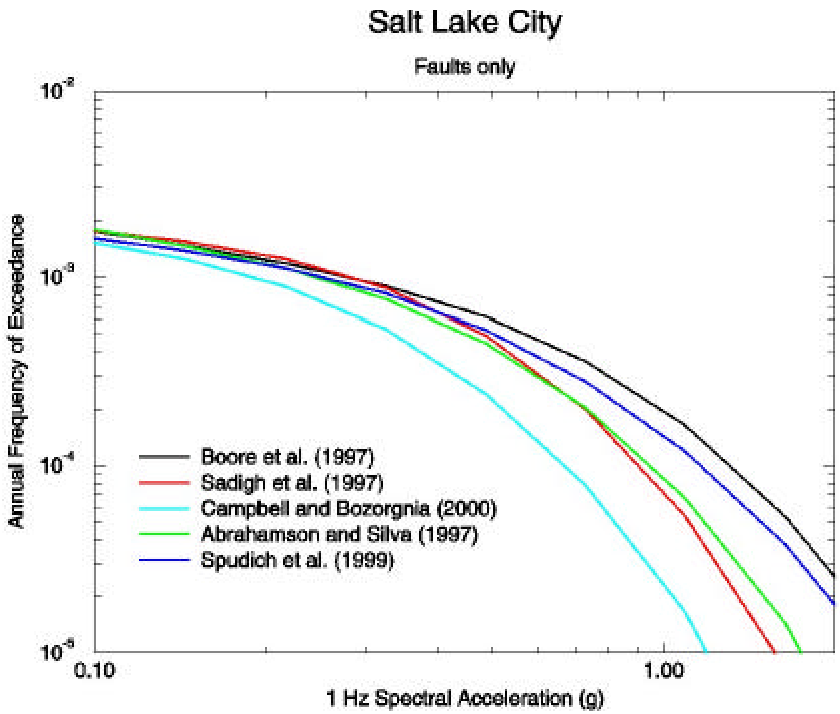
Attenuation relations
Basin response
Directivity

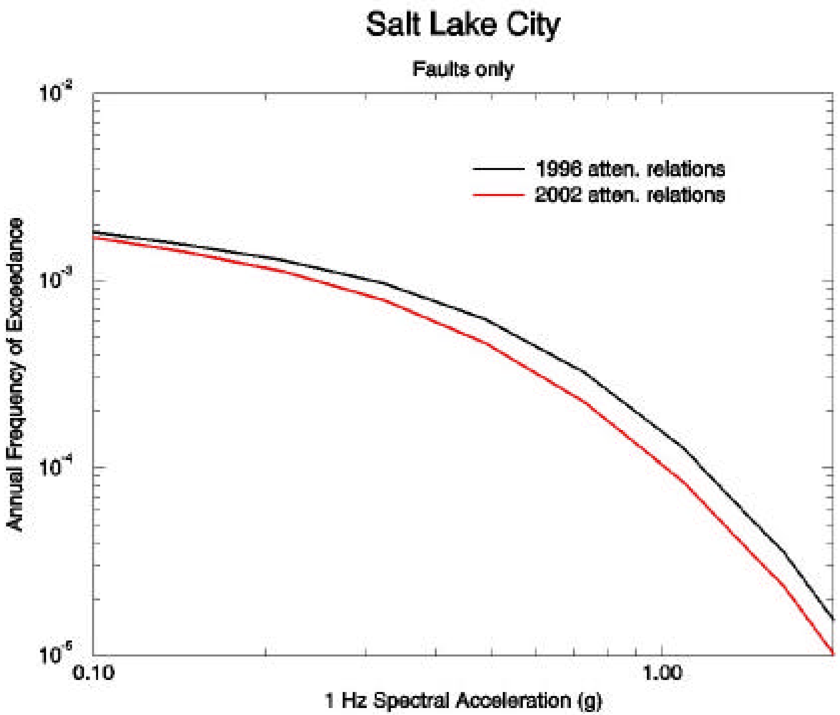
National Seismic Hazard Mapping Attenuation Relation issues:

- We need attenuation relation anchored at 760 m/s
- We need attenuation relations for different soil classes
- We need attenuation relations for distances beyond 60-80km
- We need attenuation relations for M>7.5

National hazard map issues continued

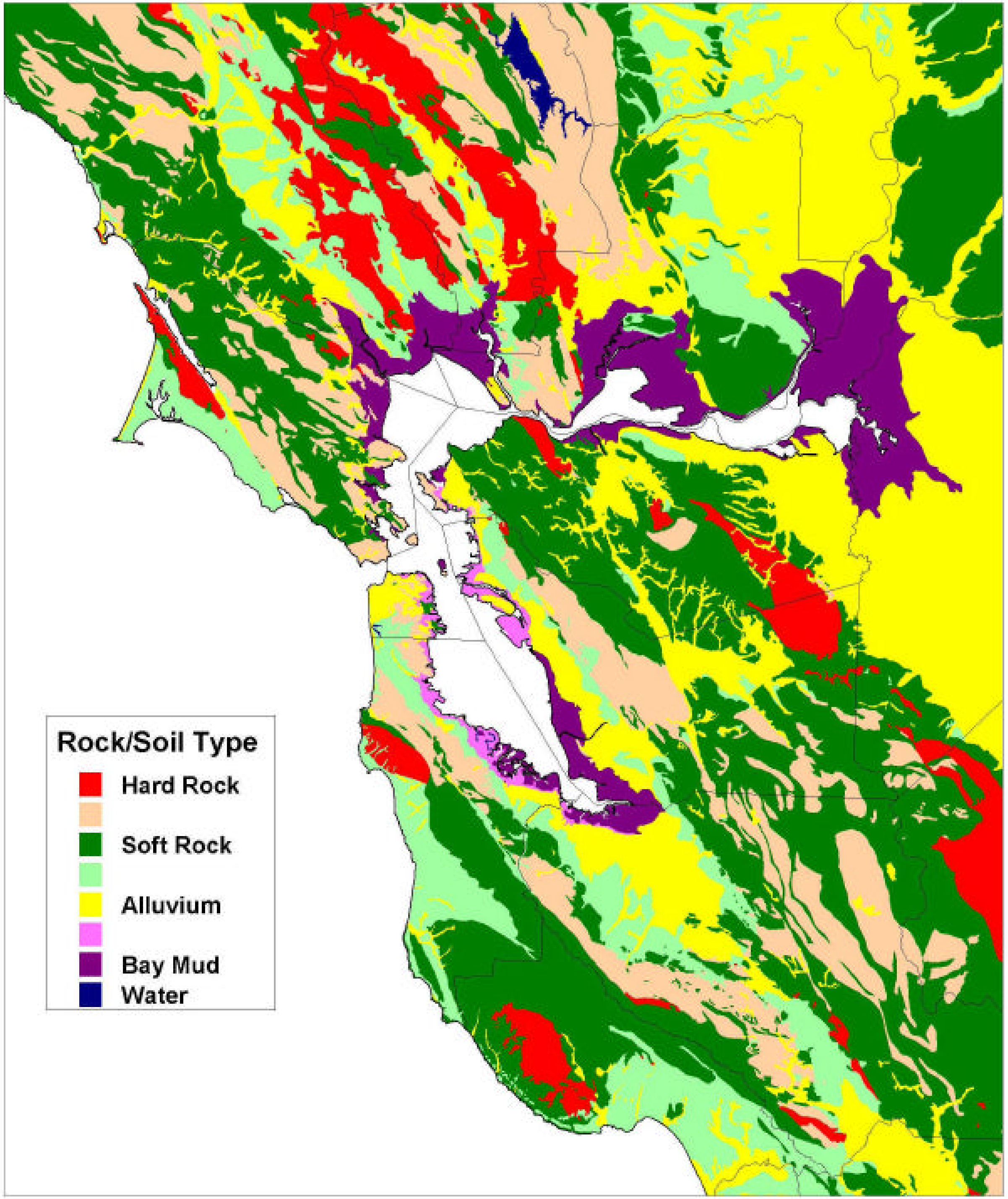
- We need directivity factors and full uncertainties
- We need attenuation relations for longer periods 3-10 seconds
- We have trouble implementing hanging wall terms


Salt Lake City
Faults only
Annual Frequency of Exceedance
1 Hz Spectral Acceleration (g)
Boore et al. (1997)
Sadigh et al. (1997)
Campbell and Bozorgnia (2000)
Abrahamson and Silva (1997)
Spudich et al. (1999)

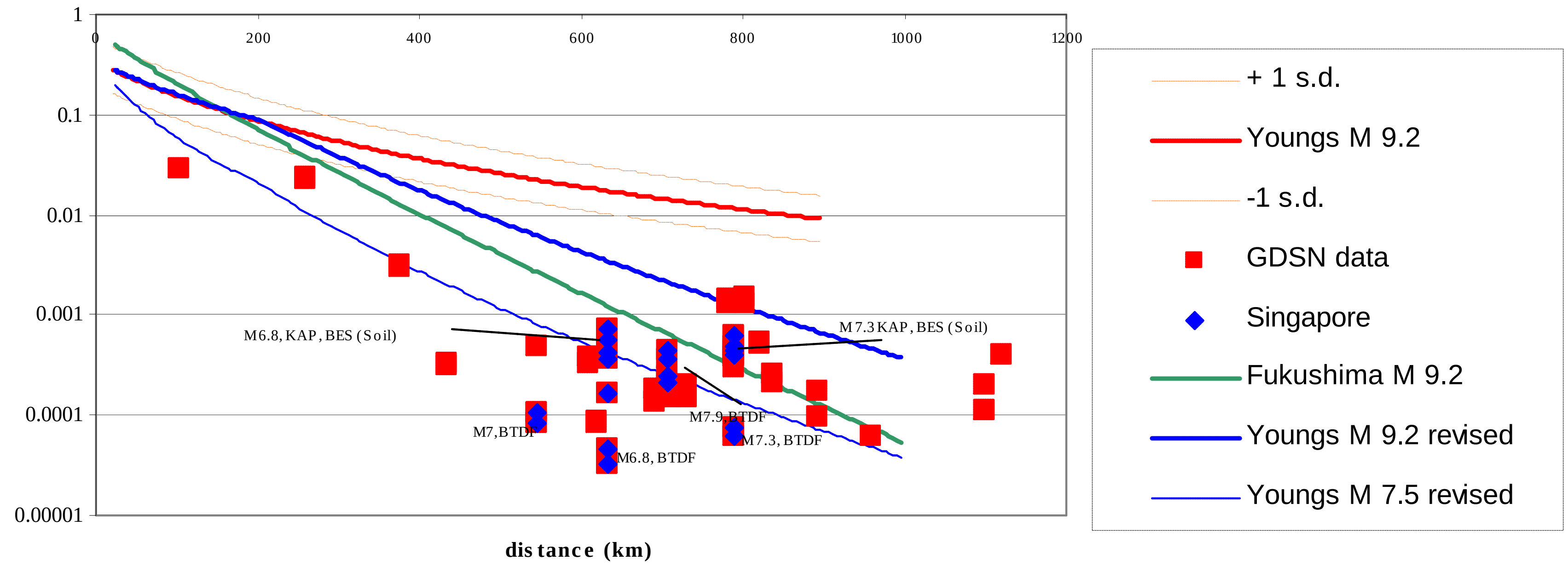

Salt Lake City
Faults only
Annual Frequency of Exceedance
1 Hz Spectral Acceleration (g)
1996 atten. relations
2002 atten. relations

Soils Map using NEHRP Vs categories

California Geological Survey



Subduction attenuation relations (M 9.2, 7.5) and strong ground motion data



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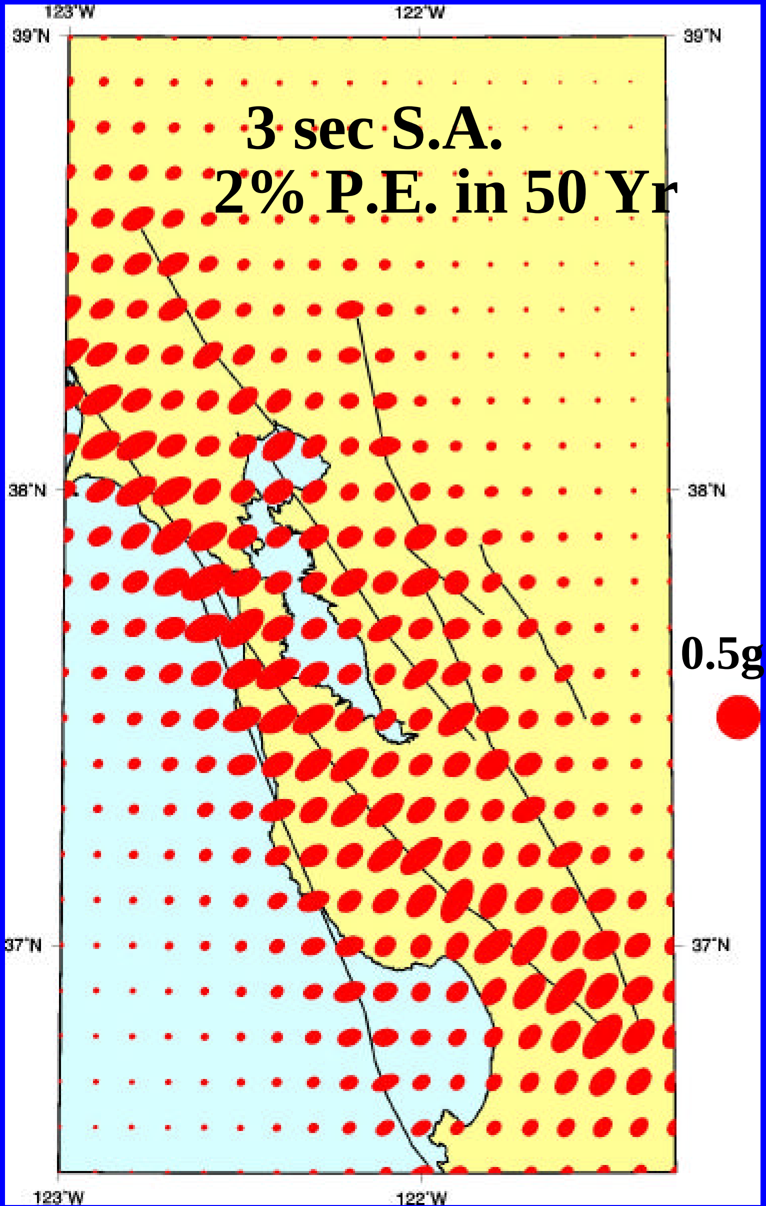
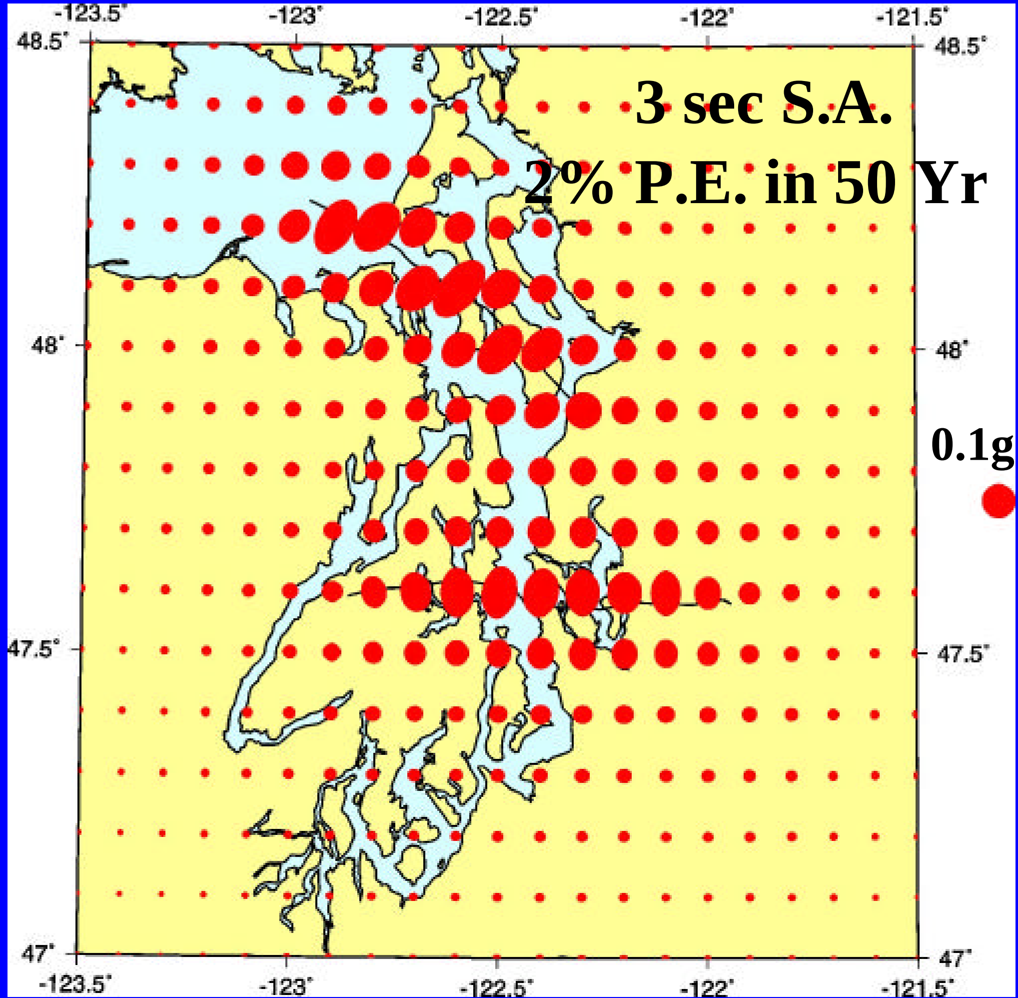
Probabilistic Ground Motions as Function of Vibration Direction and Including Rupture Directivity





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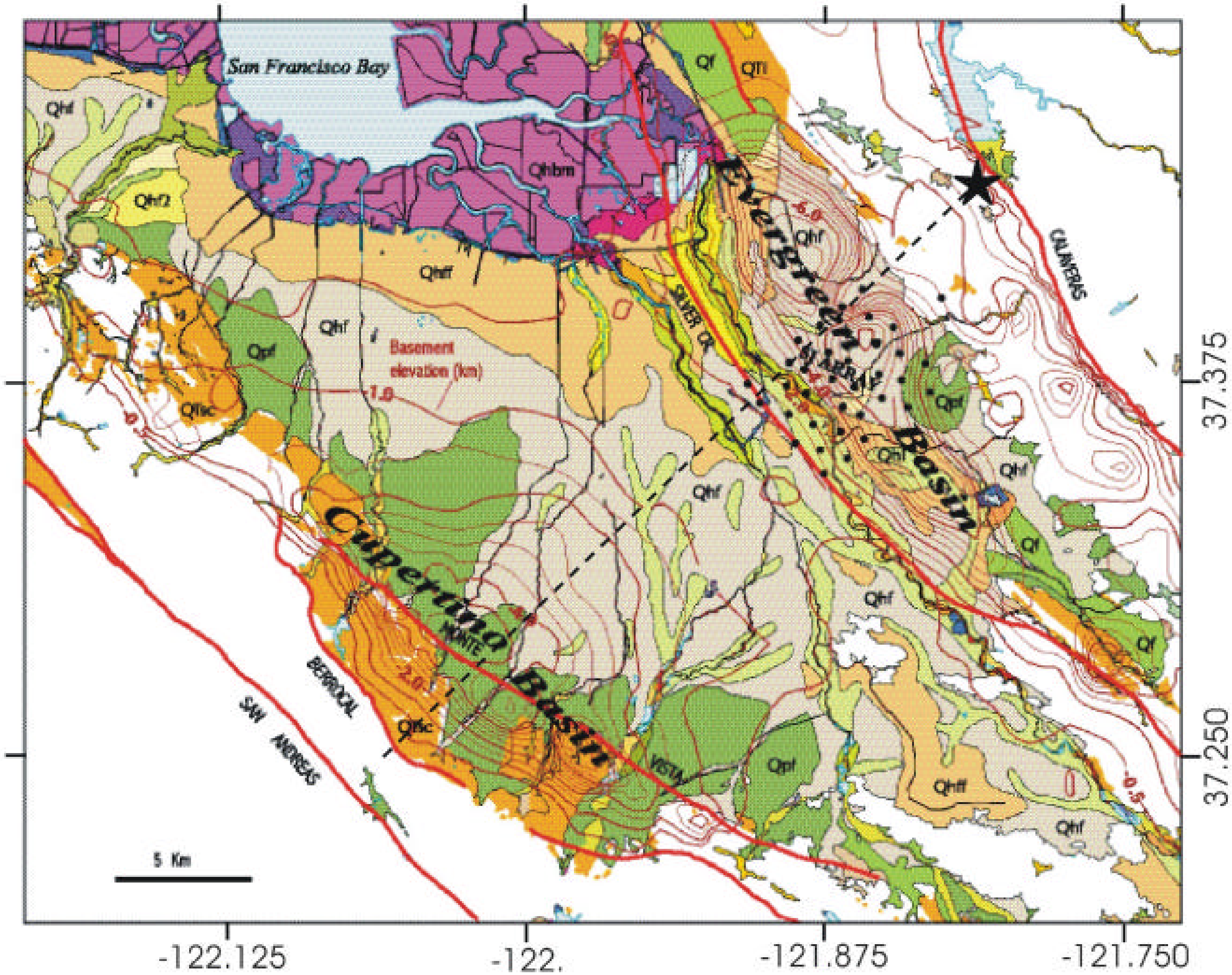
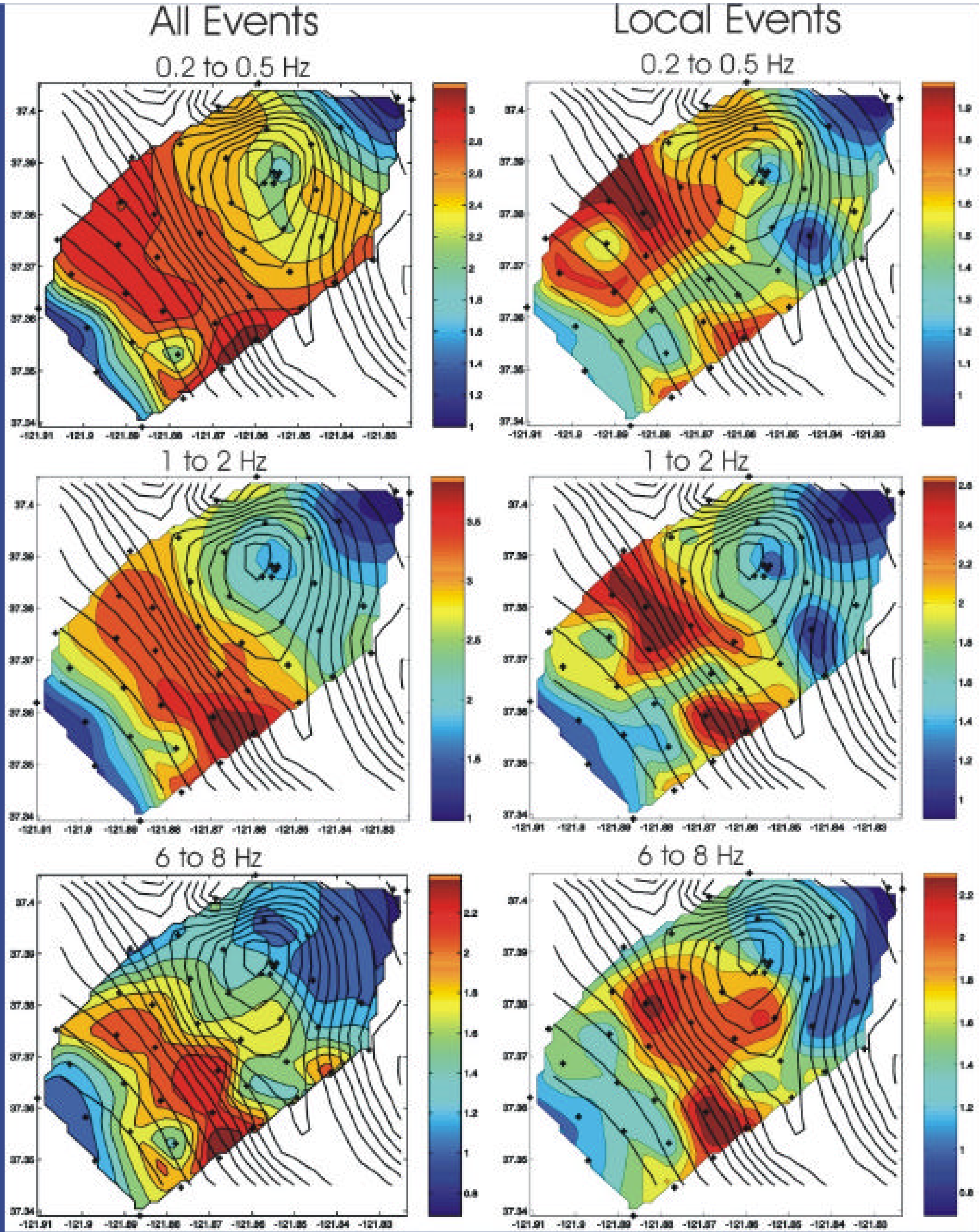
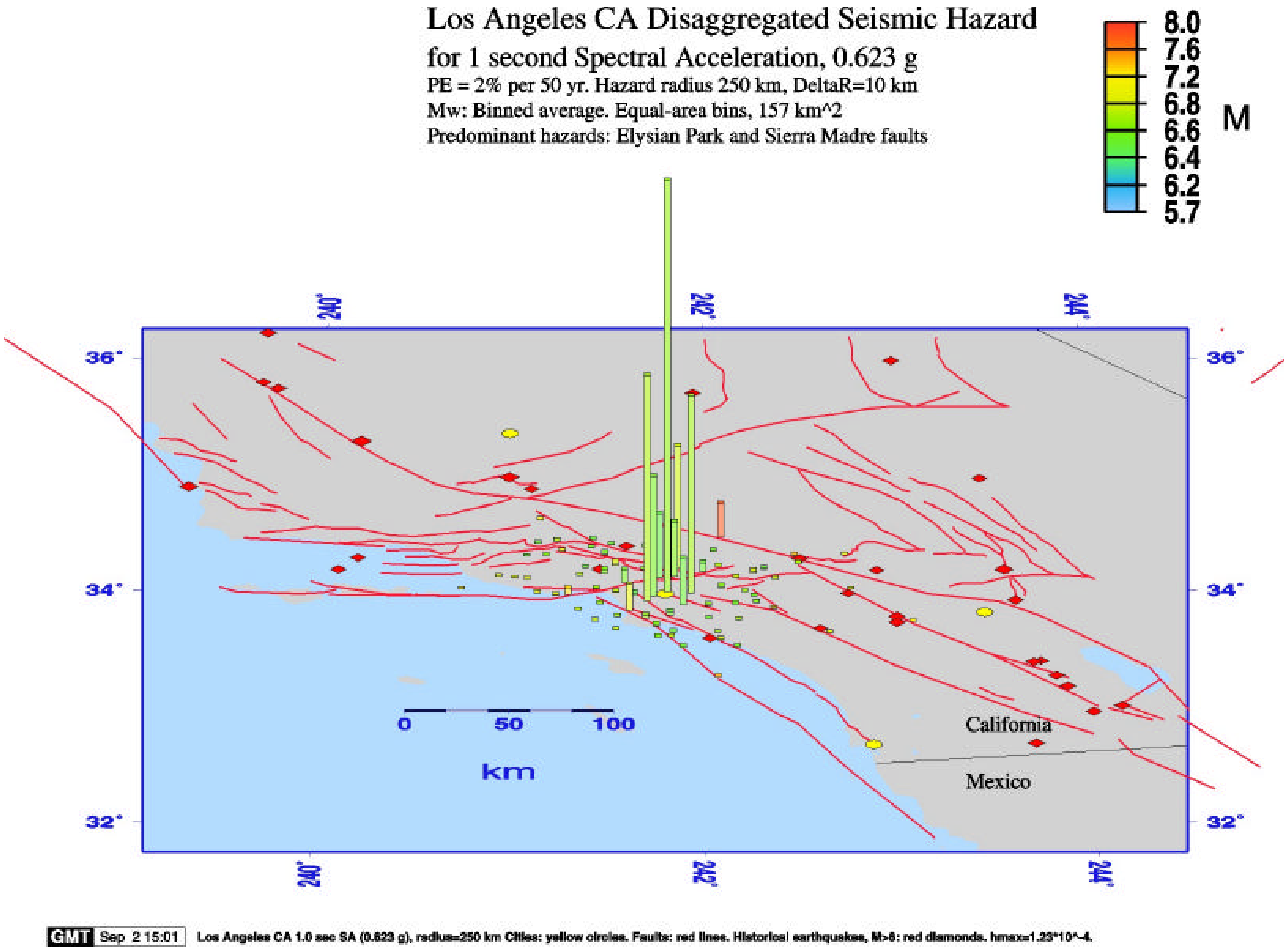

San Francisco Bay
Qhbm
Qhf
Qhf2
Qhff
Qf
Qpf
Qfsc
Basement elevation (km)
Evergreen Basin
Cupertino Basin
CALAVERAS
SILVER CR
MONTE VISTA
BERROCAL
SAN ANDREAS
5 Km
-122.125
-122.
-121.875
-121.750
37.375
37.250

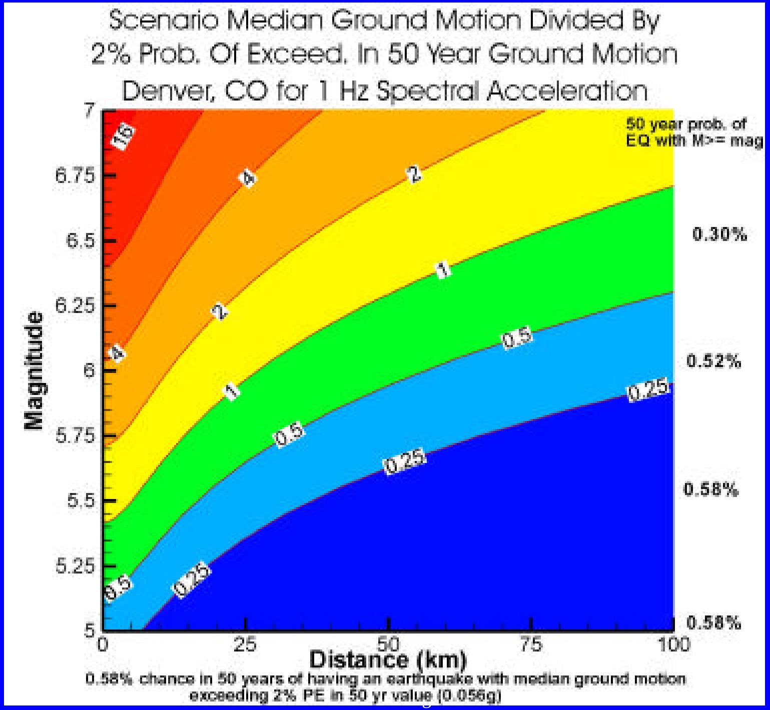


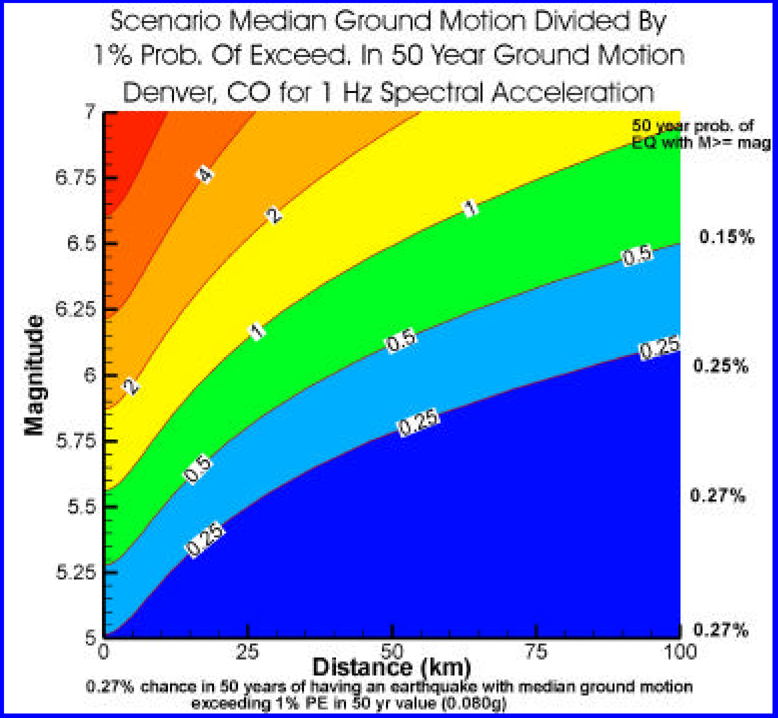
Contour maps of site amplification values in the area of the San Jose array for three different frequency ranges and two different data sets. Local events include earthquakes in the Bay Area and near the Calaveras fault. All events include the above plus regional earthquakes. The regional events include significant surface wave energy.

Engineering concerns



USGS
science for a changing world


Scenario Median Ground Motion Divided By
2% Prob. Of Exceed. In 50 Year Ground Motion
Denver, CO for 1 Hz Spectral Acceleration
50 year prob. of
EQ with M>= mag
0.30%
0.52%
0.58%
0.58%
Magnitude
Distance (km)
0.58% chance in 50 years of having an earthquake with median ground motion
exceeding 2% PE in 50 yr value (0.056g)


Scenario Median Ground Motion Divided By
1% Prob. Of Exceed. In 50 Year Ground Motion
Denver, CO for 1 Hz Spectral Acceleration
50 year prob. of
EQ with M>= mag
0.15%
0.25%
0.27%
0.27%
Magnitude
Distance (km)
0.27% chance in 50 years of having an earthquake with median ground motion
exceeding 1% PE in 50 yr value (0.080g)

Conclusions

1. Further geologic and seismic studies are needed to characterize important structures, determine the sizes of future earthquakes, and determine recurrence distributions of these events.

2. Further studies needed to understand directivity, basin response, fault-normal and fault-parallel ground motions, permanent ground deformation. Attenuation relations need to be quantified by shear-wave velocity and appropriate for magnitudes and distances used in maps.

3. Communication of hazard to engineers and public:
web site: geohazards.cr.usgs.gov/eq/
cd-roms of hazard values and design values
synthetic seismograms with deaggregations