Ground Motions and Ground Failure

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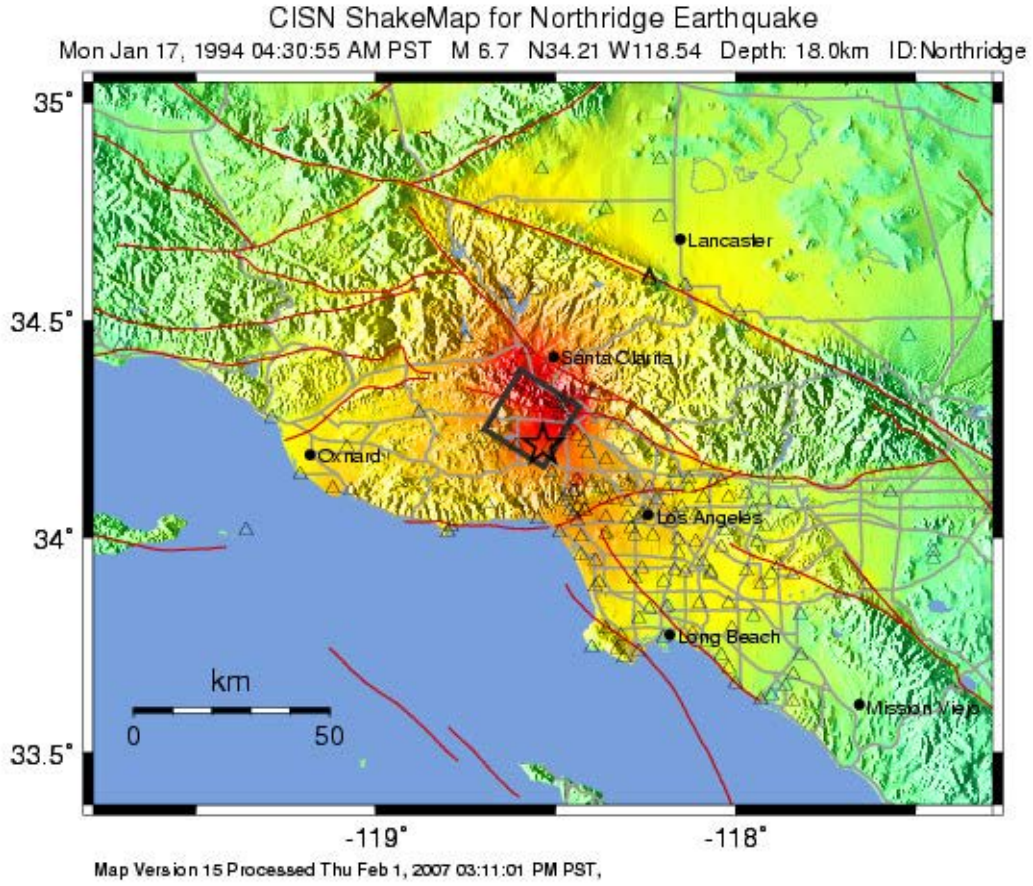
Impacts

- Ground motions well recorded
- Important features of ground motions
  - Near fault effects
  - Local damage from site amplification
- Broad range of ground failure
  - Liquefaction-related features
  - Ground failure in non-traditional soils
  - Landslides

Impacts: Ground motions

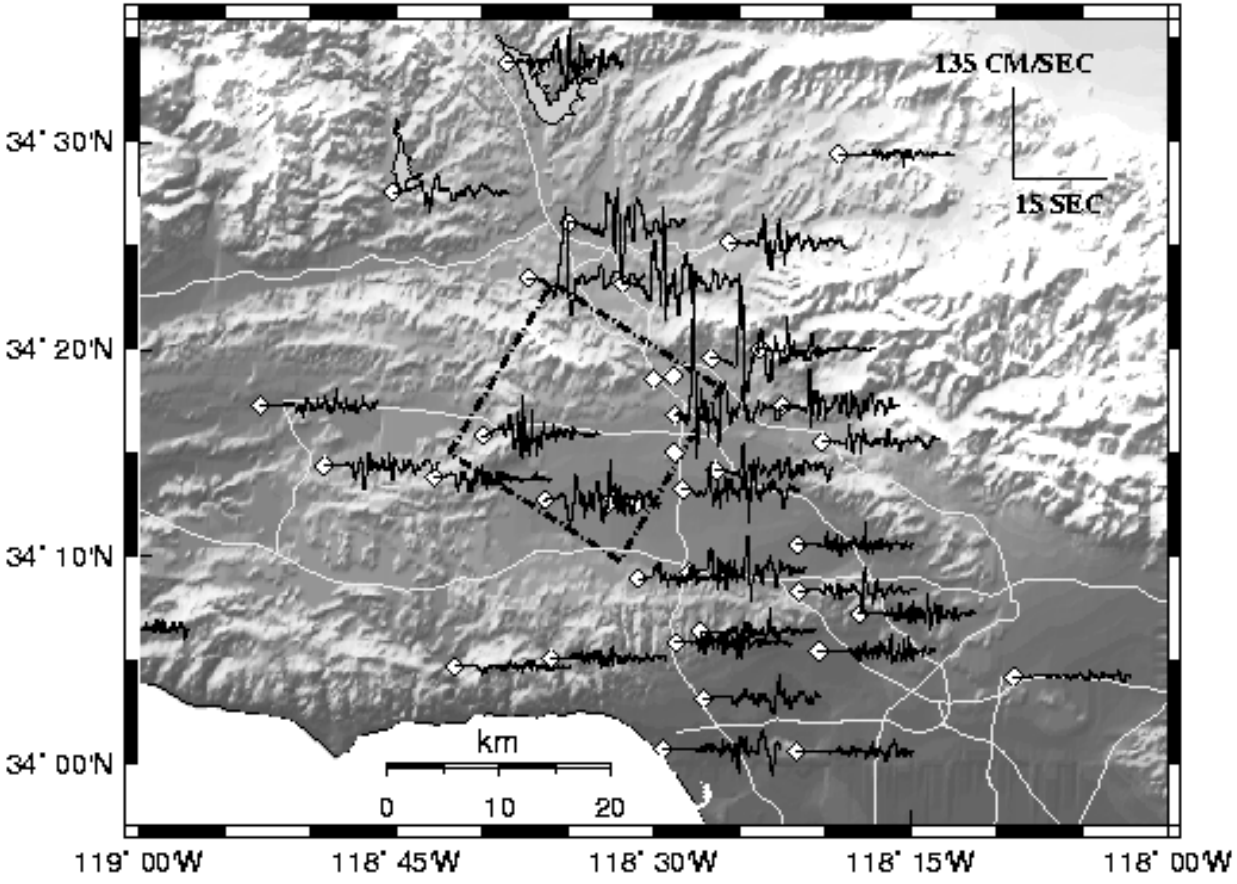
Instrumental intensity Shakemap.



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	*8.1-16*	*16-31*	*31-60*	*60-116*	*>116*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Source: http://earthquake.usgs.gov/earthquakes/shakemap/sc/shake/Northridge/

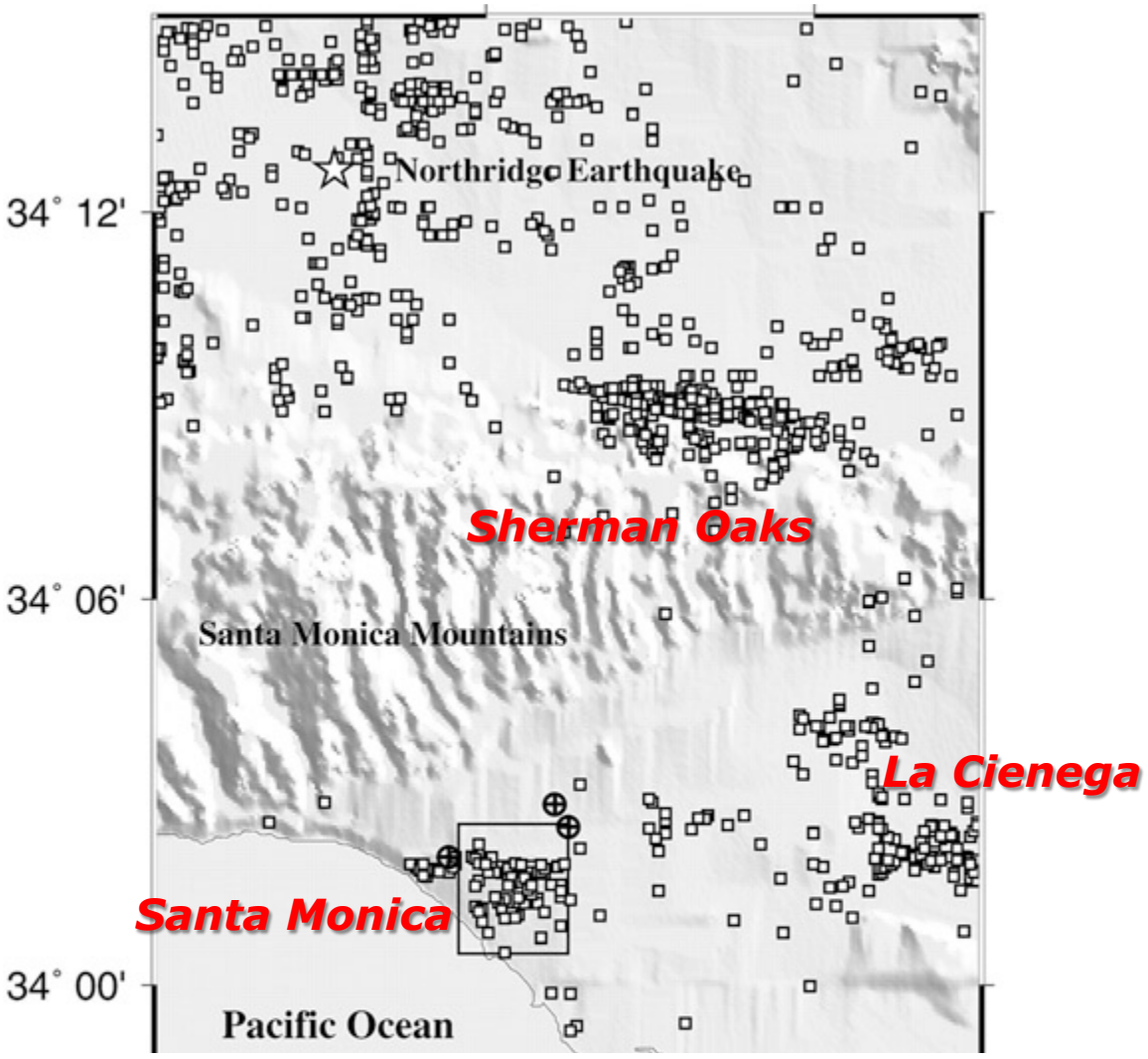
Impacts: Ground motions



Source: http://pasadena.wr.usgs.gov/office/wald/CUREe.html

Impacts: Ground motions

Clustering of red-tagged buildings



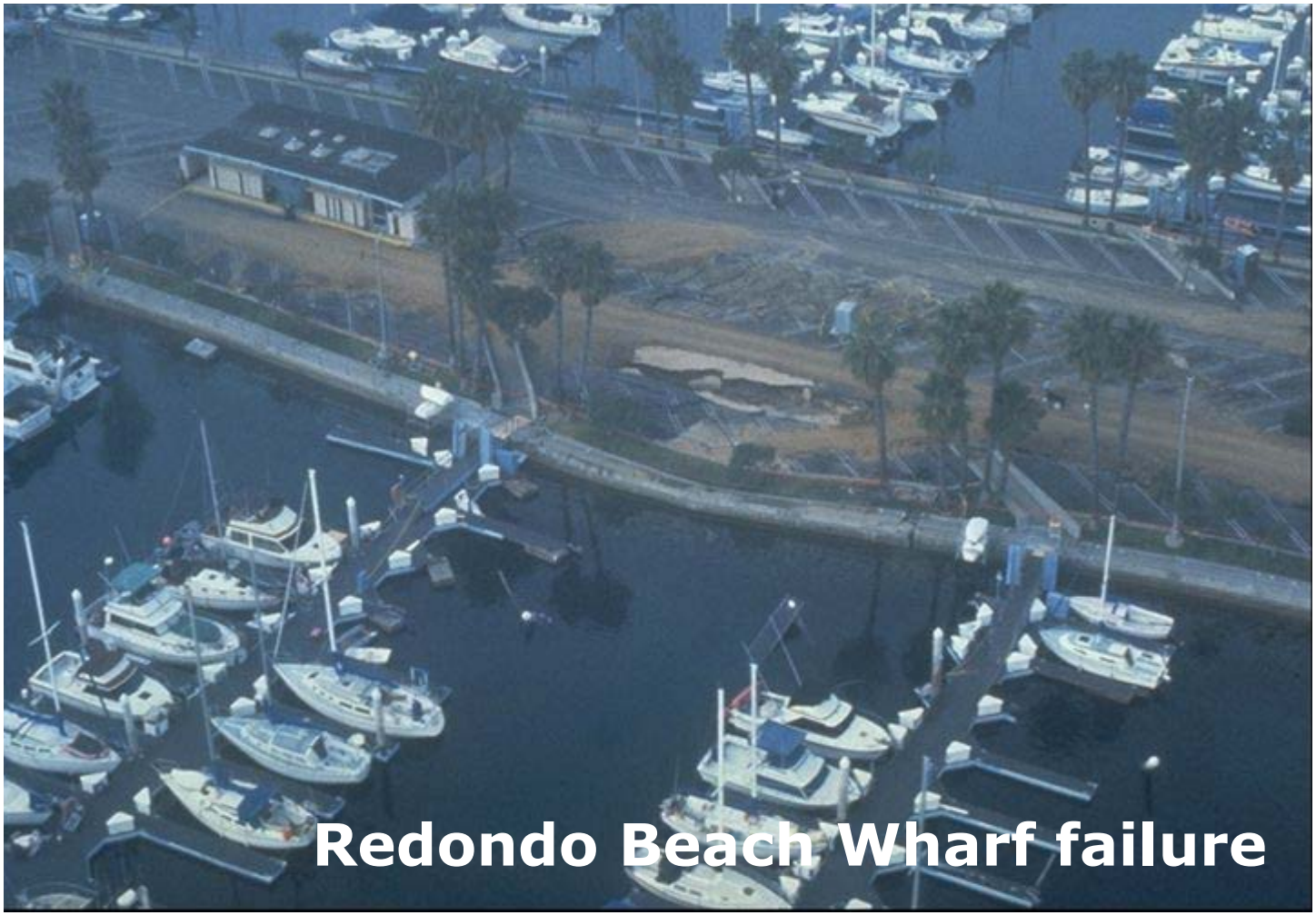
Source: Davis et al., 2000: *Science*.

Impacts: Liquefaction

Tapo Canyon flow failure

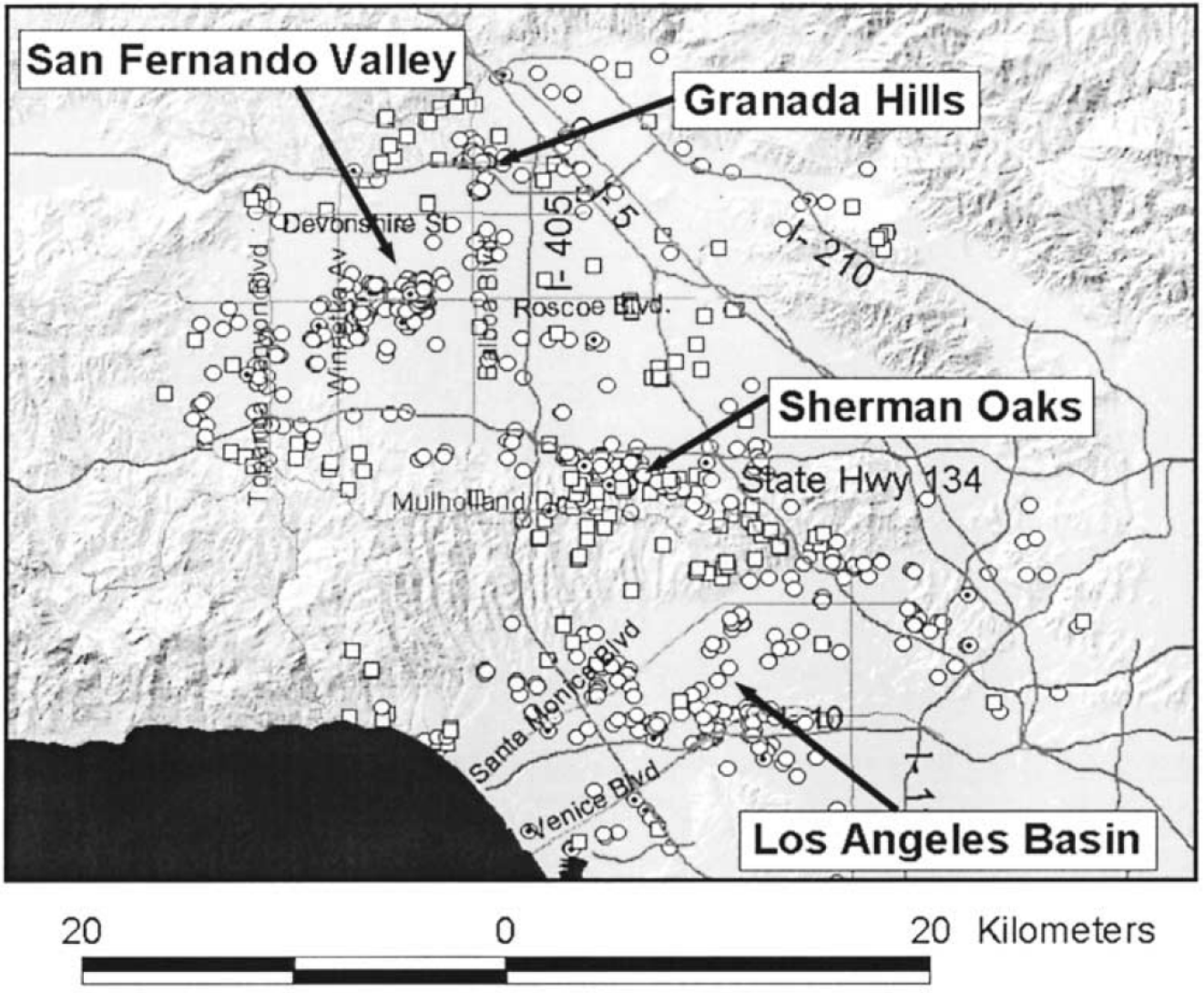
Source: Yoshi Moriwaki

Impacts: Liquefaction



Source: Stewart et al., 1994: *EERC 94-08*.

Impacts: Liquefaction



Pipe breaks – many in liquefaction zones

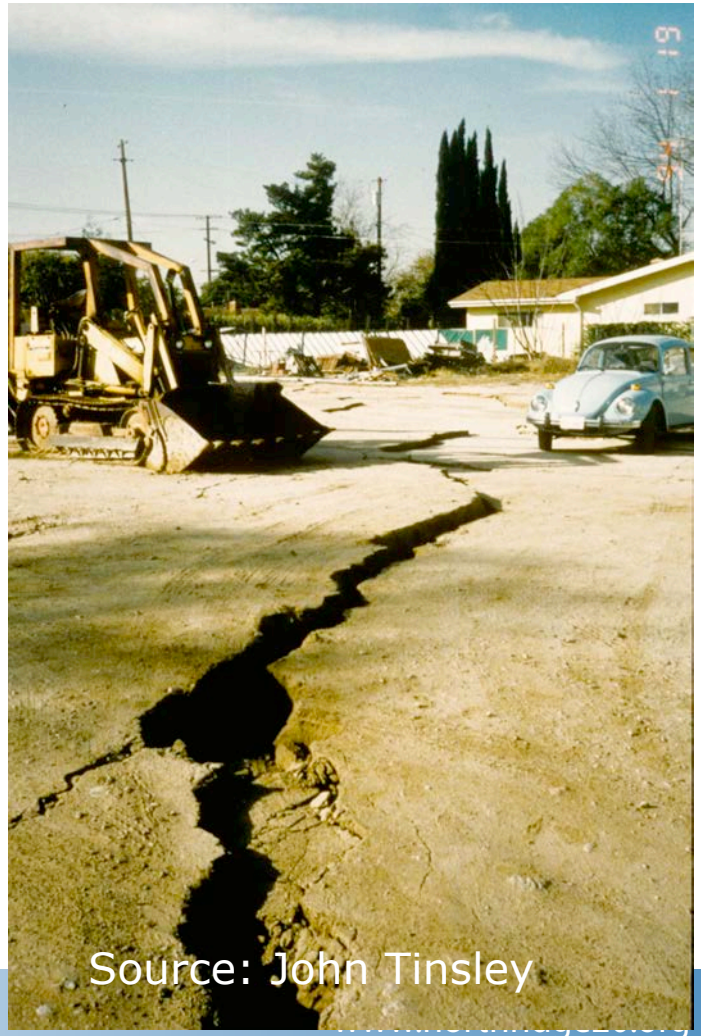
Source: Jeon and O'Rourke, 2005; Stewart et al., 1996 *BSSA*.

Impacts: Ground failure in fine-grained soils

Balboa Blvd., Grenada Hills

Source: Kerry Sieh

Malden St., Northridge



Source: John Tinsley

Impacts: Ground failure in compacted fills

Ground deformations in unsaturated, compacted fills soils

Source: Alan Kropp & David McMahon

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Impacts: Landslides

Widespread seismic landslides.

Incidents of ‘valley fever’

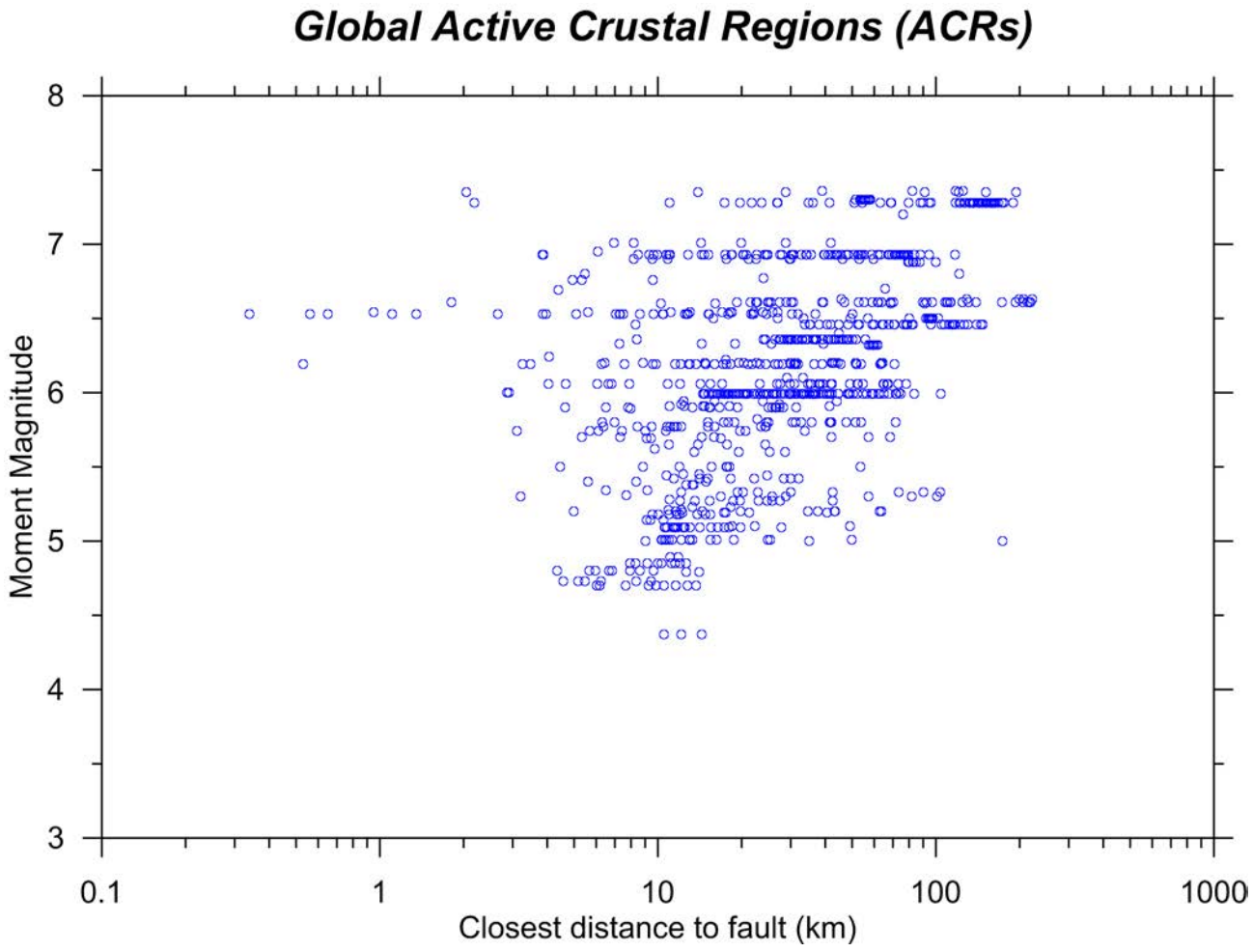
Source: Jibson, 2002: *Surveys in Geophysics*

Outcomes: Ground motion

- NGA program:
  - Improved processing and dissemination of ground motions.
  - Ground motion prediction models, including near-source and site effects
- Building code ground motions:
  - Mapping
  - Site amplification

Outcomes: Ground motion prediction

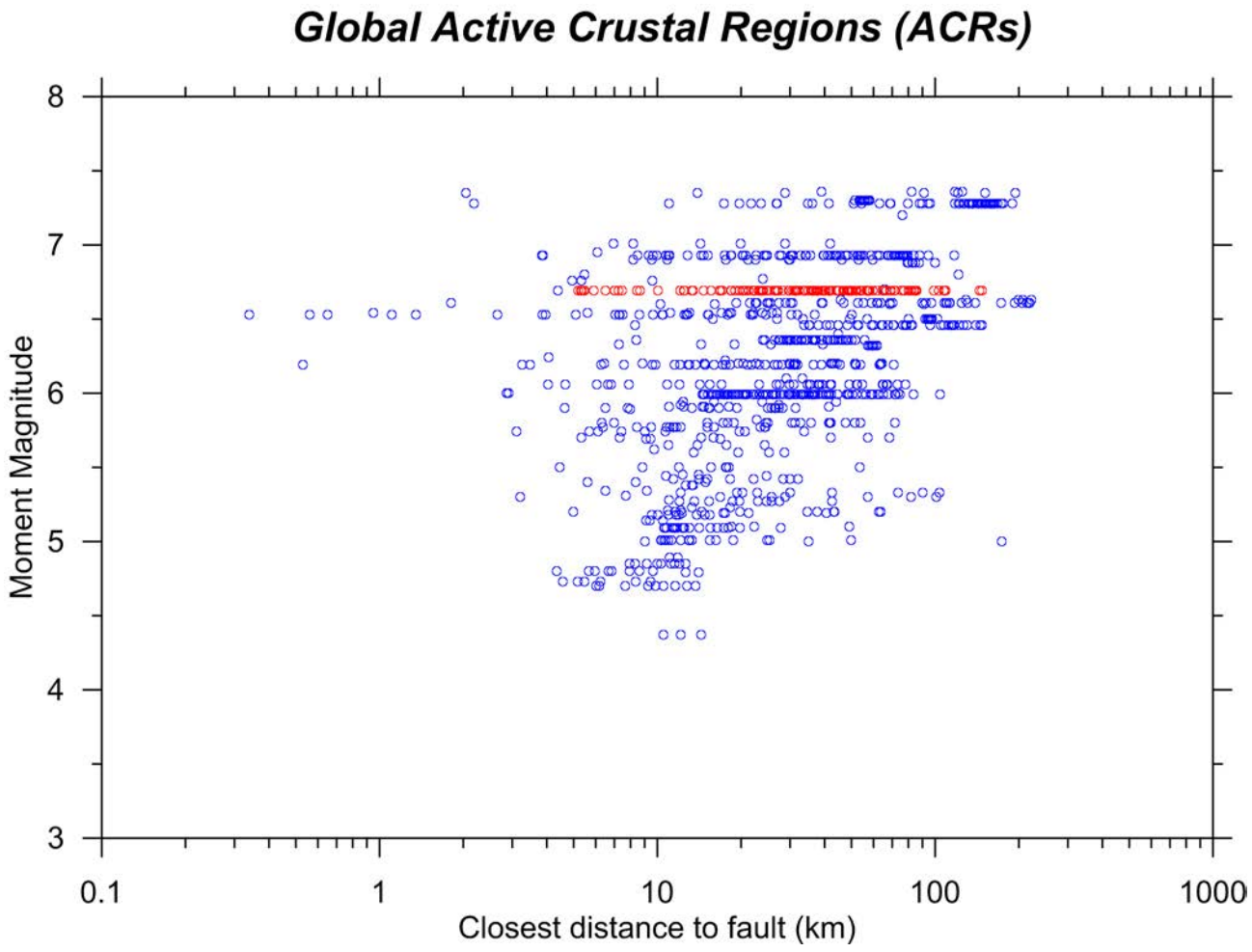
Pre-Northridge recordings



Outcomes: Ground motion prediction

Pre-Northridge recordings

Northridge recordings

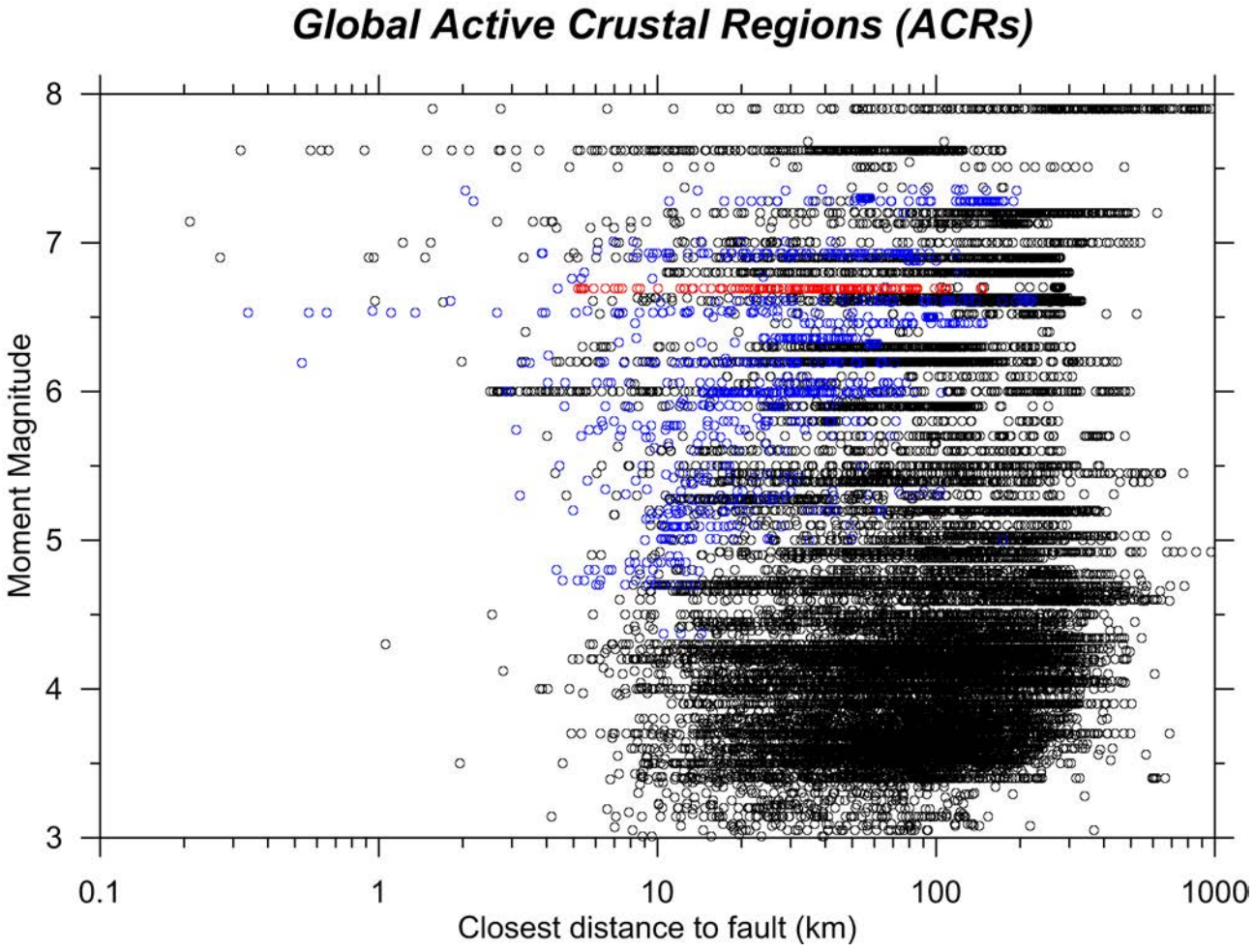


Outcomes: Ground motion prediction

Pre-Northridge recordings

Northridge recordings

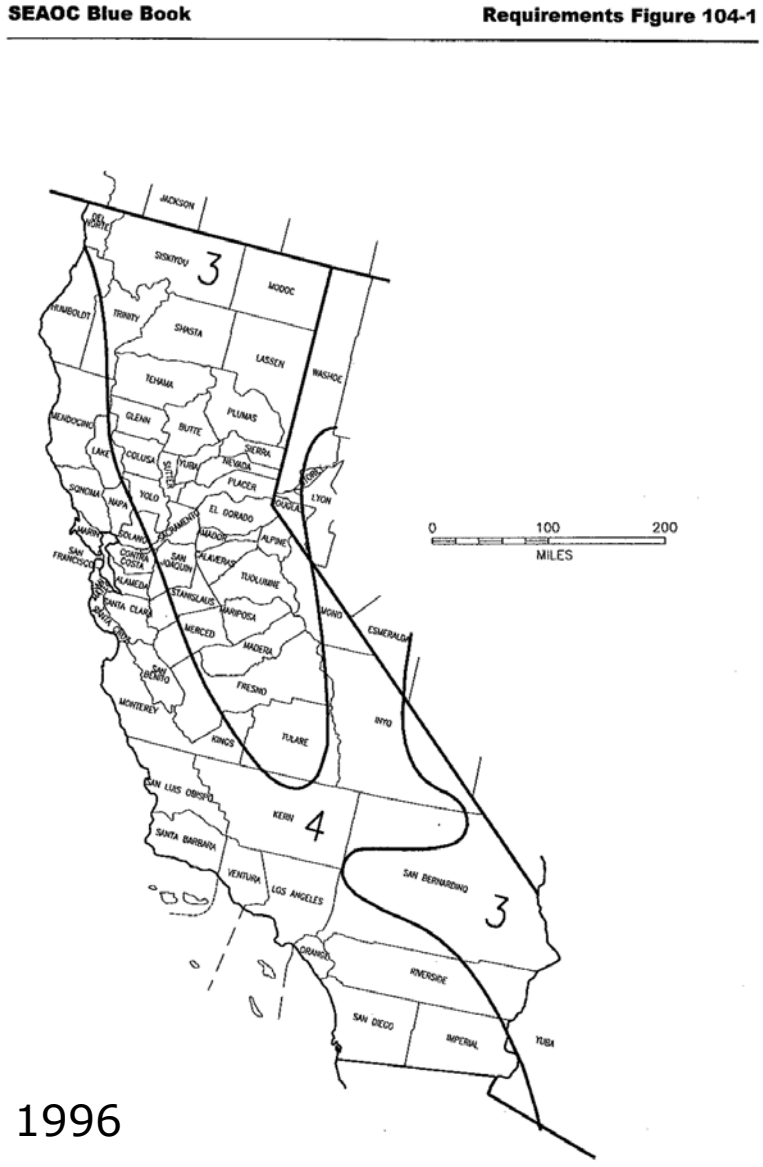
Current DB (NGA-West 2)



Outcomes: Building code ground motions

Before Northridge:

1. Zone map



Source: Blue Book, 1996

Outcomes: Building code ground motions

Before Northridge:

1. Zone map
2. **Linear PGA site factor**

Table 104-2. *Site Coefficients*[1]

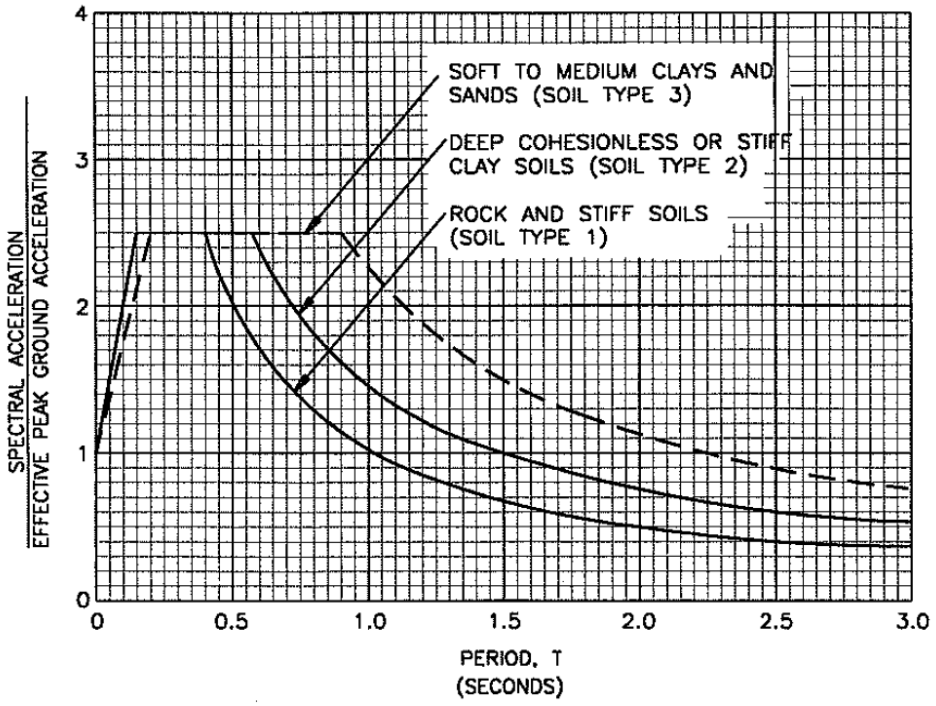
Type	Description	S Factor
S_1	A soil profile with either: 1. A rock-like material characterized by a shear-wave velocity greater than 2,500 feet per second, or by other suitable means of classification or: 2. Medium stiff to stiff or medium dense to dense soil conditions where soil depth is less than 200 feet	1.0
S_2	A soil profile with predominantly medium dense to dense or medium stiff to stiff soil conditions, where soil depth exceeds 200 feet	1.2
S_3	A soil profile containing more than 20 feet of soft to medium stiff clay but not more than 40 feet of soft clay	1.5
S_4	A soil profile characterized by a shear wave velocity of less than 500 feet per second, and containing more than 40 feet of soft clay	2.0

Source: Blue Book, 1996

Outcomes: Building code ground motions

Before Northridge:

1. Zone map
2. Linear PGA site factor
3. **Site-dependent spectral shapes**



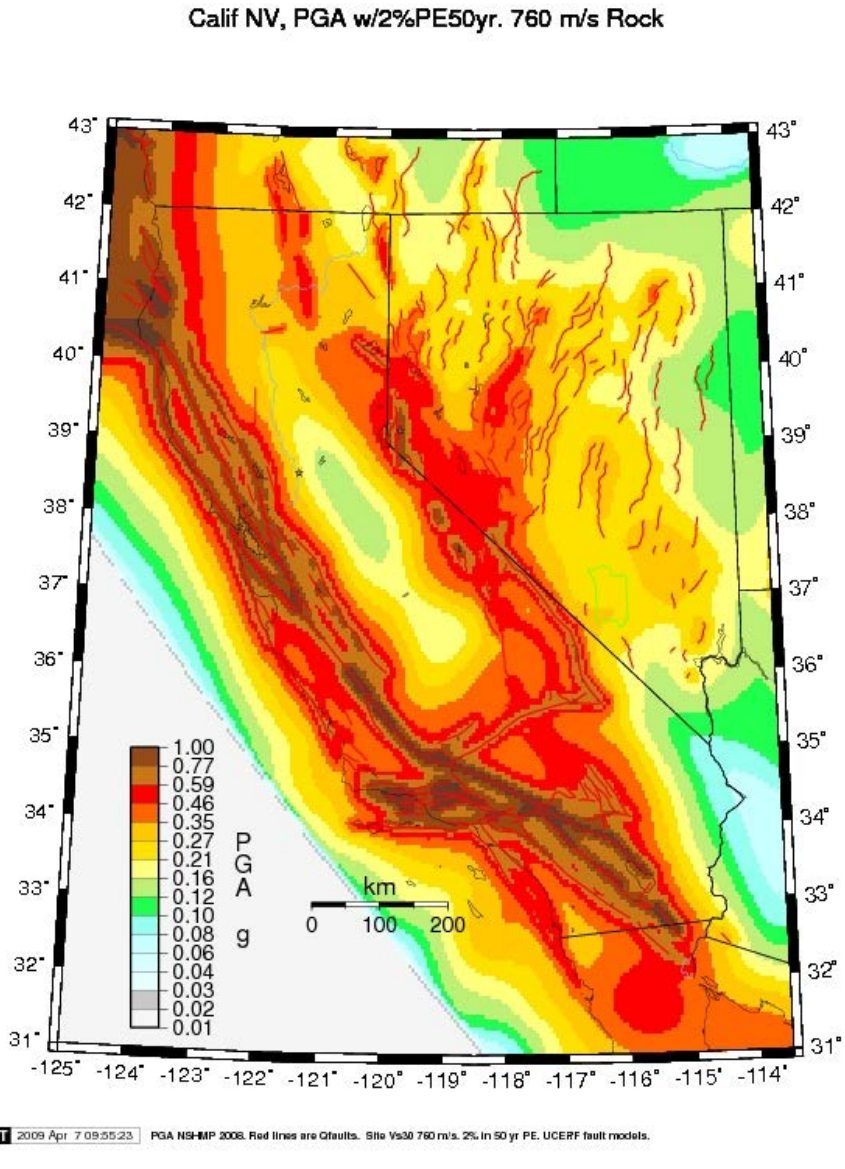
Source: Blue Book, 1996

Outcomes: Building code ground motions

Since Northridge:

1. USGS online hazard maps

Source:
http://earthquake.usgs.gov/hazards/



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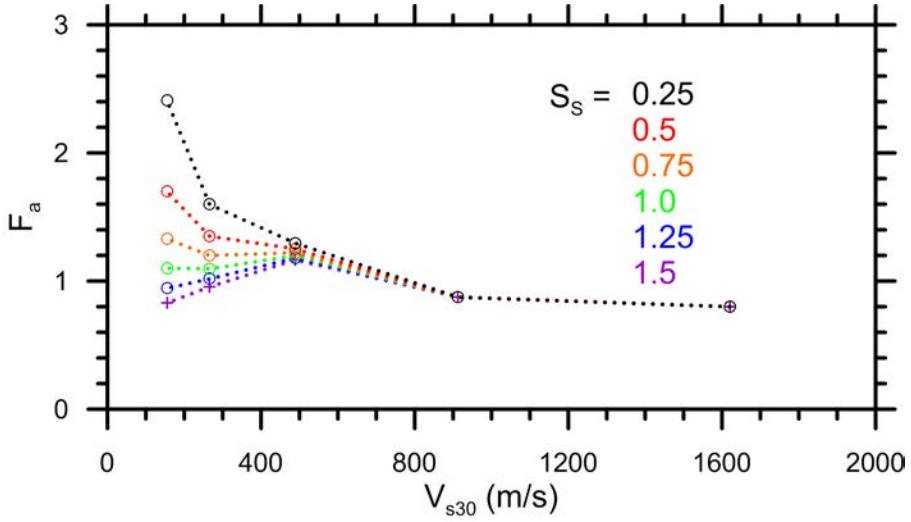
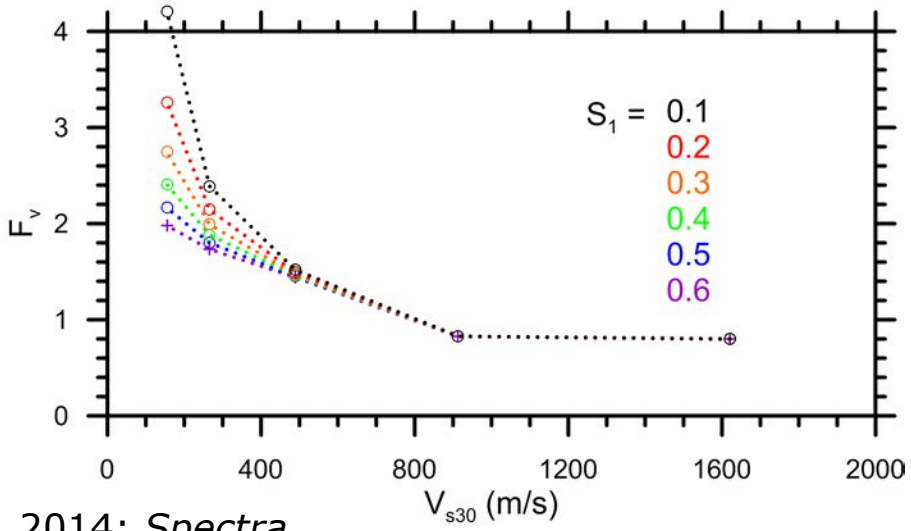
Outcomes: Building code ground motions

Since Northridge:

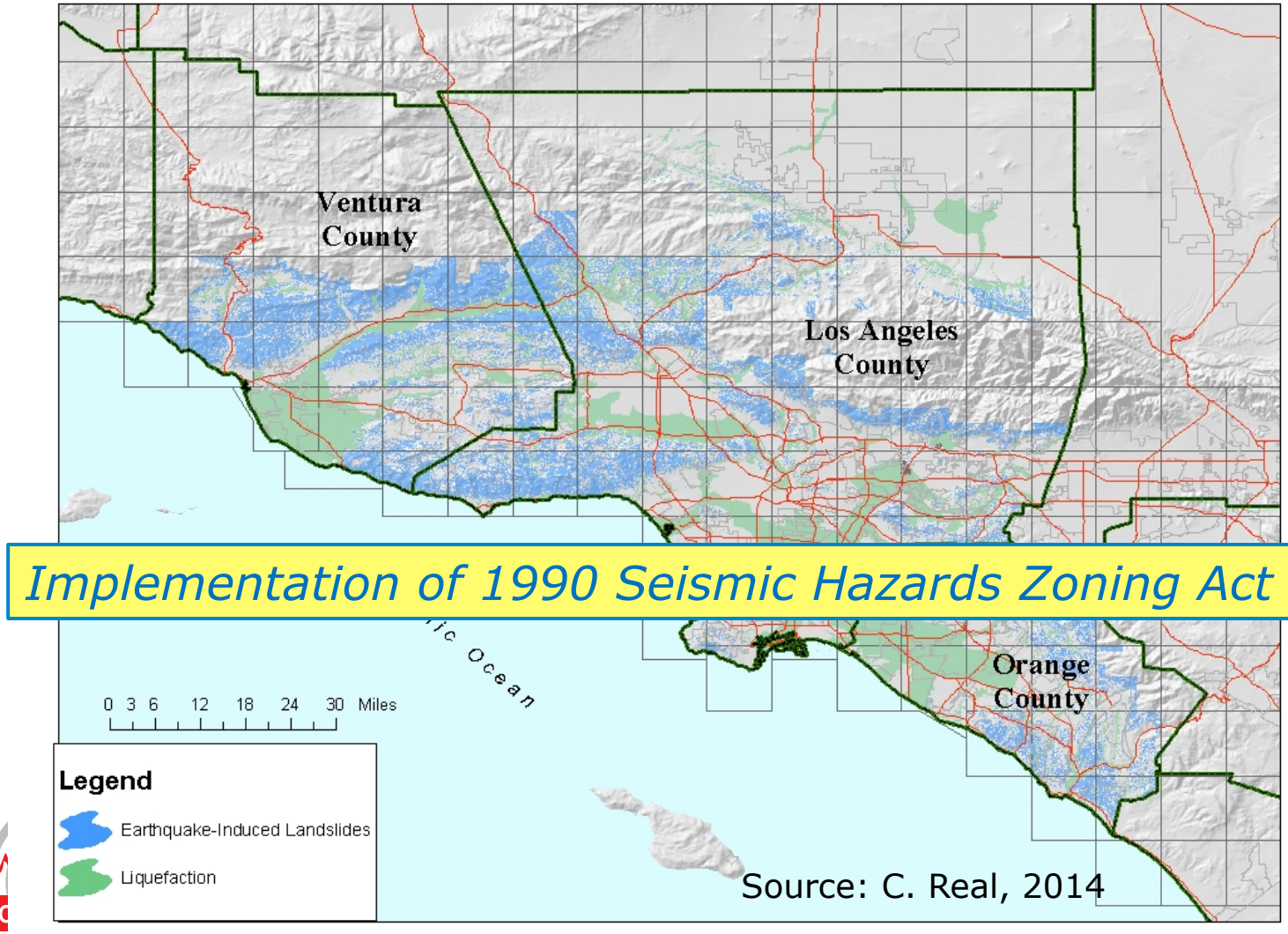
1. USGS online hazard maps
2. **Nonlinear site factors for short- and mid-periods (F_a and F_v)**
3. Procedures for site-specific analysis





Source: Seyhan & Stewart, 2014: *Spectra*.

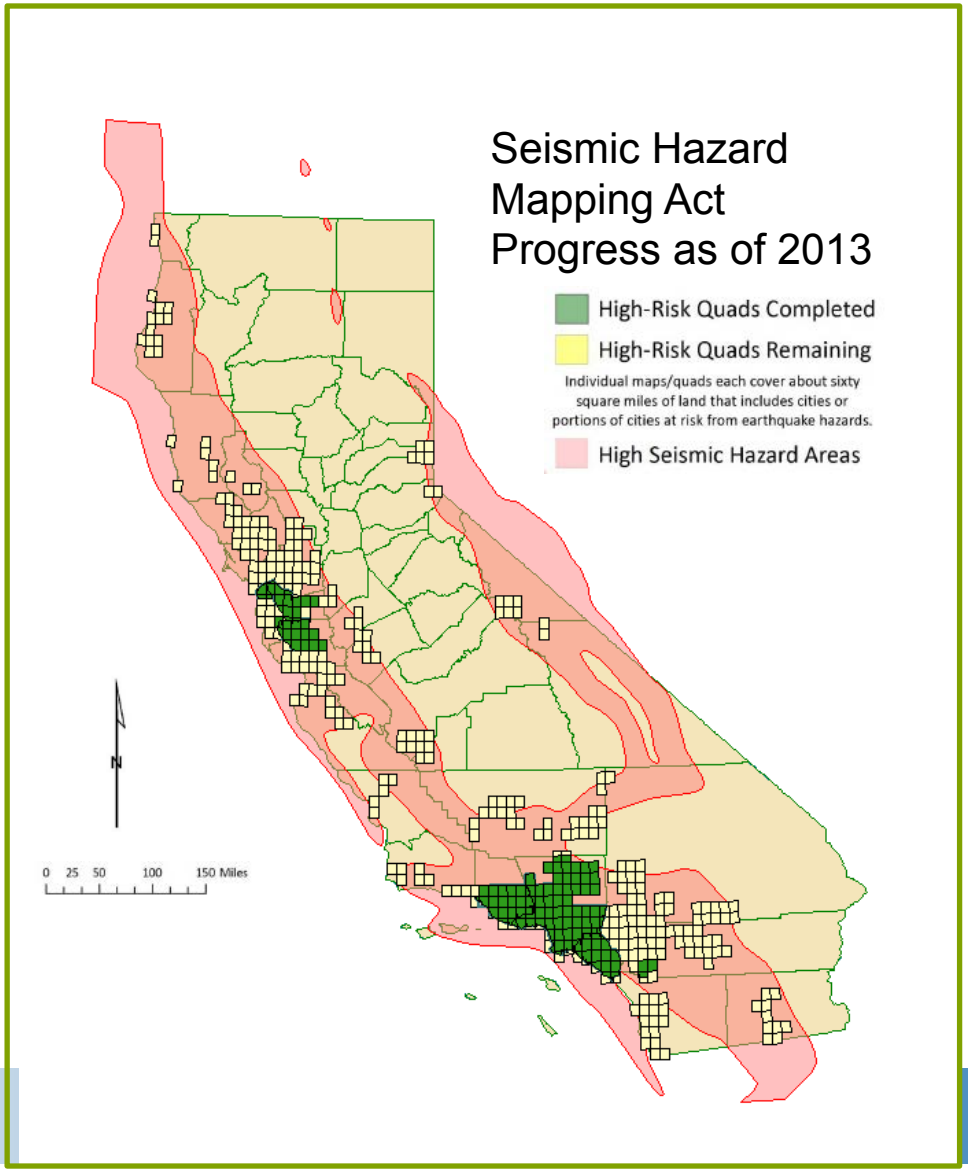
Outcomes: Ground failure



Implementation of 1990 Seismic Hazards Zoning Act

Outcomes: Ground failure

Many high-risk areas remain unmapped.



Source: C. Real, 2014

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Next Steps and Recommendations

- Sustained funding for ground motion research
  - Maintenance of arrays
  - Updating of databases
  - Periodic development of improved GMPEs
- Develop community ground failure database & models
- Increase funding for CGS seismic hazards mapping (liquefaction, landslides, faults)

Friday Breakout

Ground motion, site response, and ground failure

- Ground motion simulations. **Paul Somerville**, URS.
- GMPE advancements. **Yousef Bozorgnia**, PEER.
- Ground motion selection/scaling. **Christine Goulet**, PEER.
- Nonlinear site response. **Youssef Hashash**, UIUC.
- Liquefaction and ground failure. **Tom Holzer**, USGS.
- Slope stability and compacted fill. **Tom Blake**, Fugro.
- Panel discussion.

Next Steps

- Periodic updating of GMPEs
  - Incorporate new data
  - Apply lessons learned from validated simulations
  - Especially critical for Pacific NW and CEUS
- Next-generation ground failure models
  - Fine-grained materials
  - Effects of ground failure on structures
- More complete seismic hazards mapping
  - Liquefaction and landslides
  - Surface fault rupture