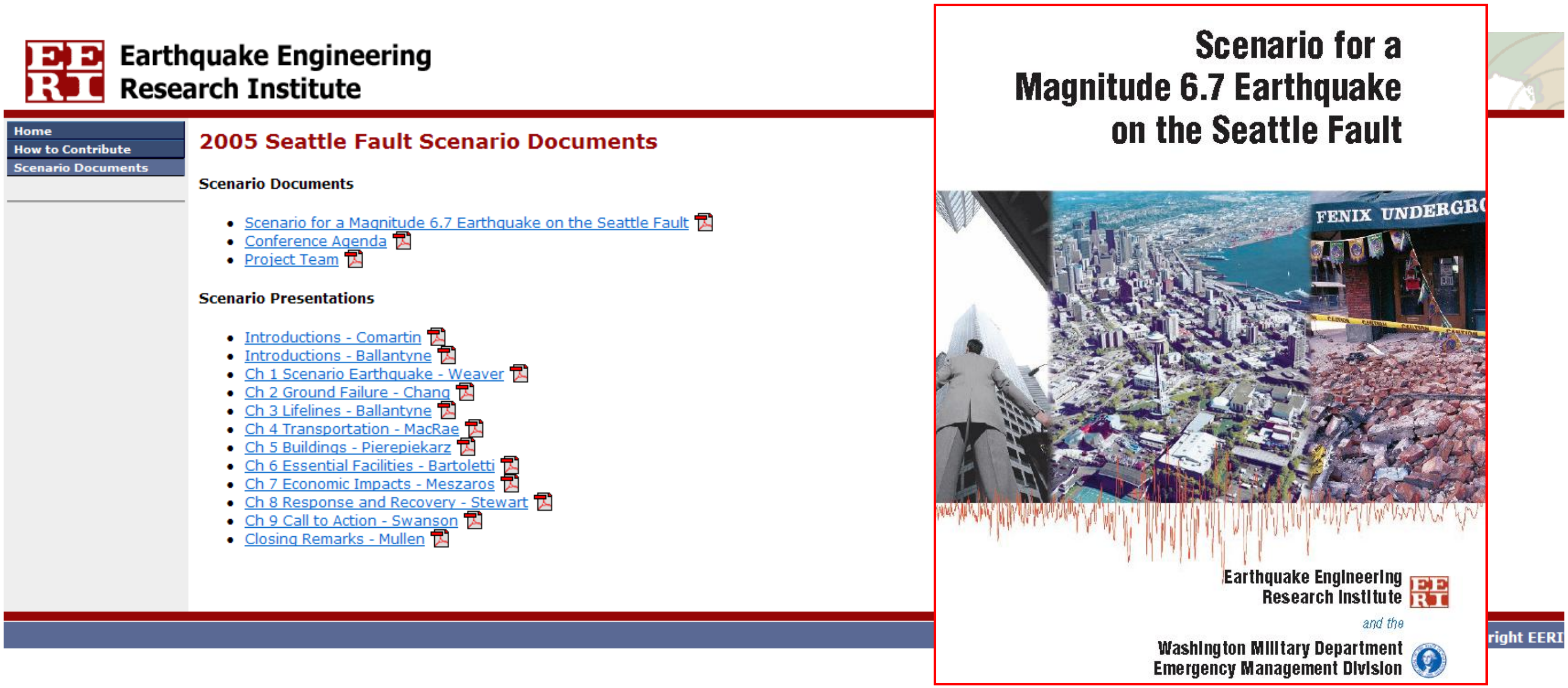
Earthquakes and Seismicity – What to Know

- Intensity Scales- Richter versus Mercalli
- Seismic Wave Types – P,S, Surface
  - Compressional – Fastest
  - Shear – Slower – does not travel through liquid
  - Surface – Slowest Causes most of damage
  - Location determined by difference of P and S from multiple stations
  - Other terms: Focus, Epicenter
- Ground Responses to Earthquakes
  - Shaking
  - Fault Rupture
  - Lateral Spreading
  - Landslide
  - Liquefaction
    - The collapse of soil structure under undrained conditions resulting in loss of bearing capacity and fluidization
  - Tsunamis
  - Amplification of effects by ground conditions

Earthquakes and Seismicity – What to Know, cont’d

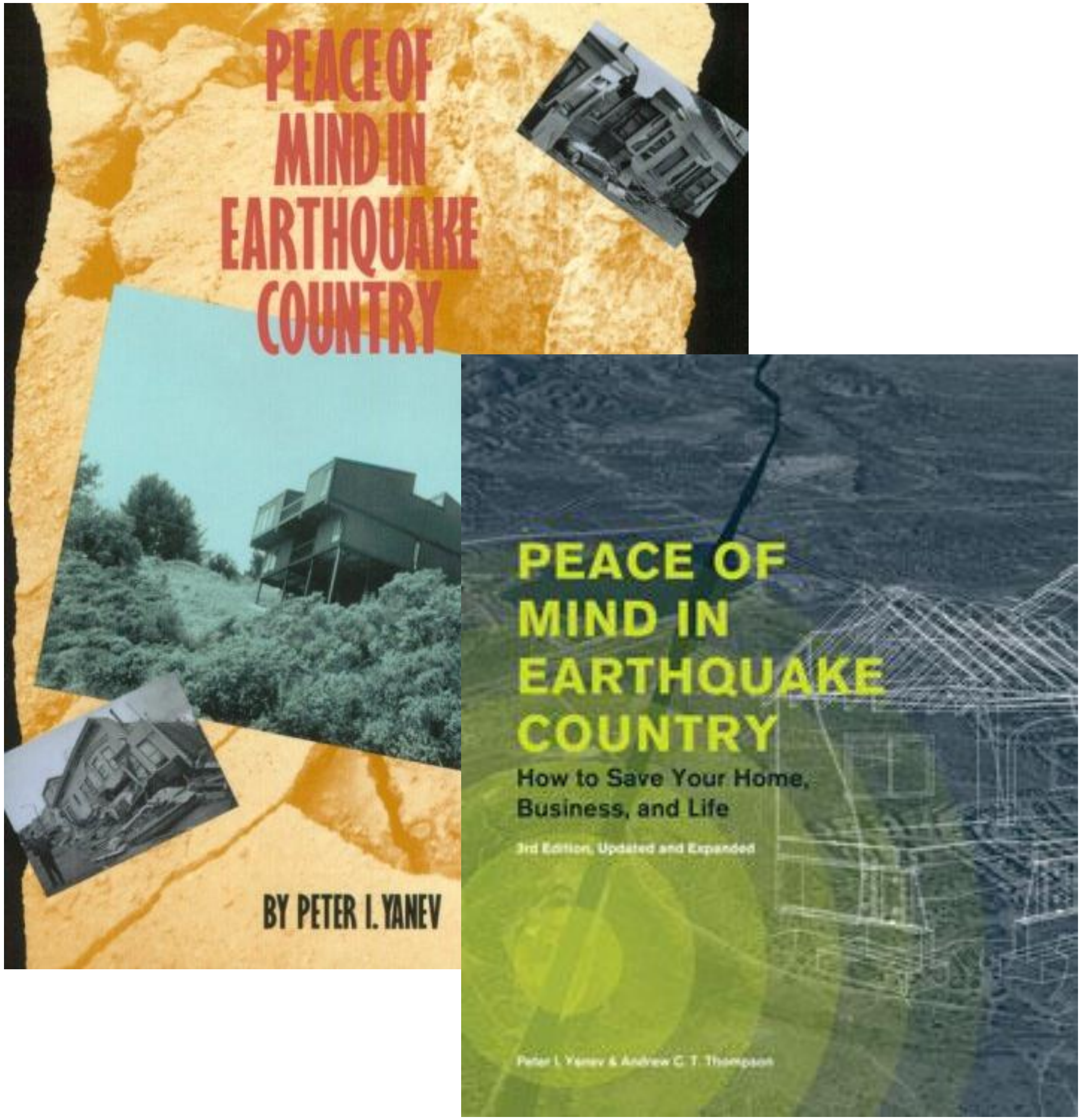
- Studying Earthquakes and Finding Faults
  - Seismic monitoring
  - Stereographic projection and fault motion – “beach balls”
  - Seismic reflection
  - Trenching and indicators of recurrence intervals
- NW fault types, their typical earthquakes, recurrence intervals
  - Subduction Zone earthquakes
    - Local deep earthquakes
    - Great earthquakes on the entire zone
  - Shallow crustal earthquakes – Seattle Fault, Tacoma Fault
- Vulnerable Structures

Source Materials



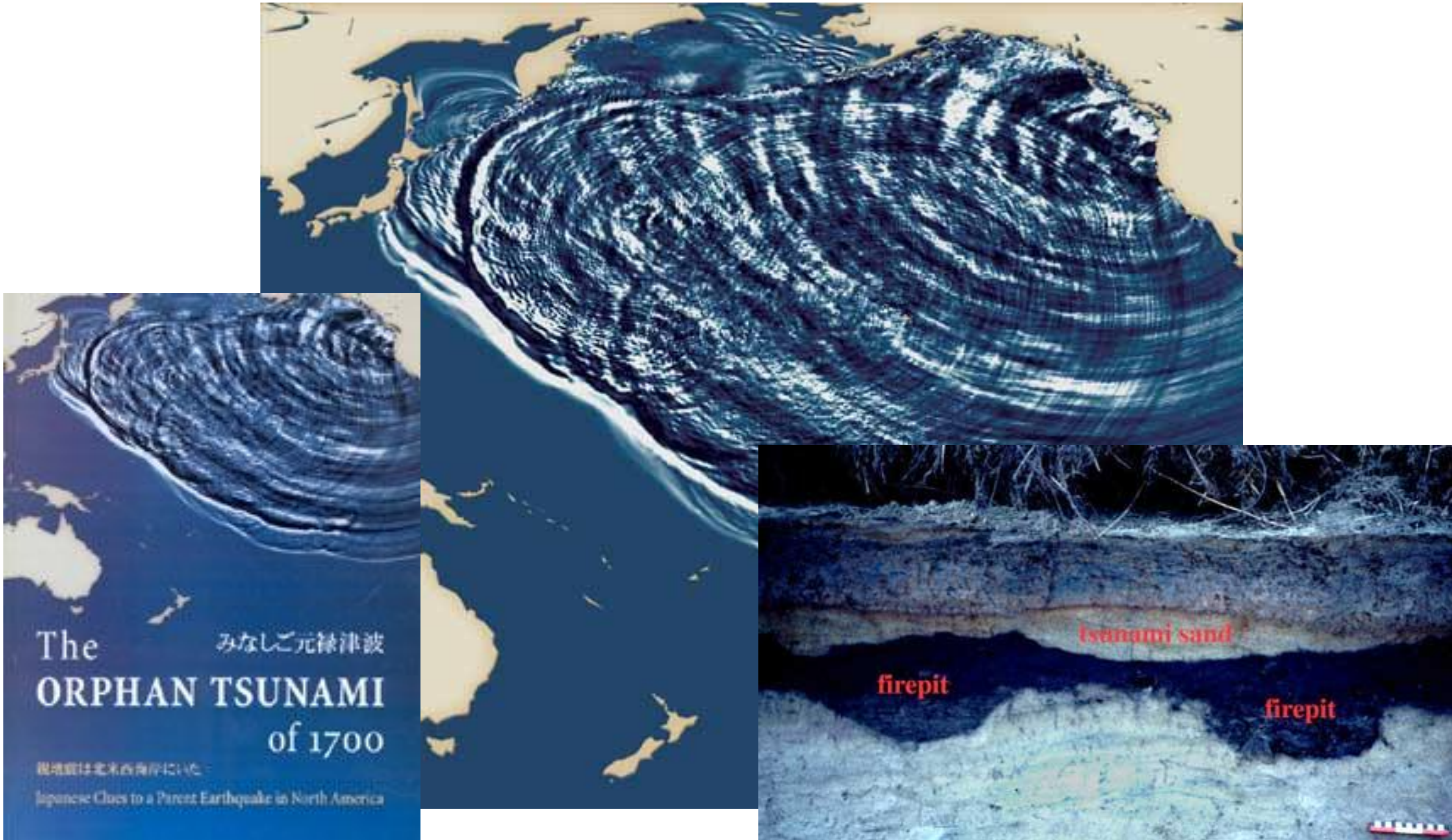
http://seattlescenario.eeri.org/documents.php

http://seattlescenario.eeri.org/documents/EQ ScenarioFullBook.pdf



Peter Yanev, Peace of Mind in Earthquake Country – How to Save Your Home and Life, Chronicle Books 2nd Edition (also out in 3rd Edition with Andrew Thompson on Risk Assessment)

Atwater, Musumi-Rokkaku, Satake,Tsuji, Ueda, and Yamaguchi, 2005, The Orphan Tsunami of 1700



http://pubs.usgs.gov/pp/pp1707/ and University of Washington Press

The Great Post Urbanization Earthquake

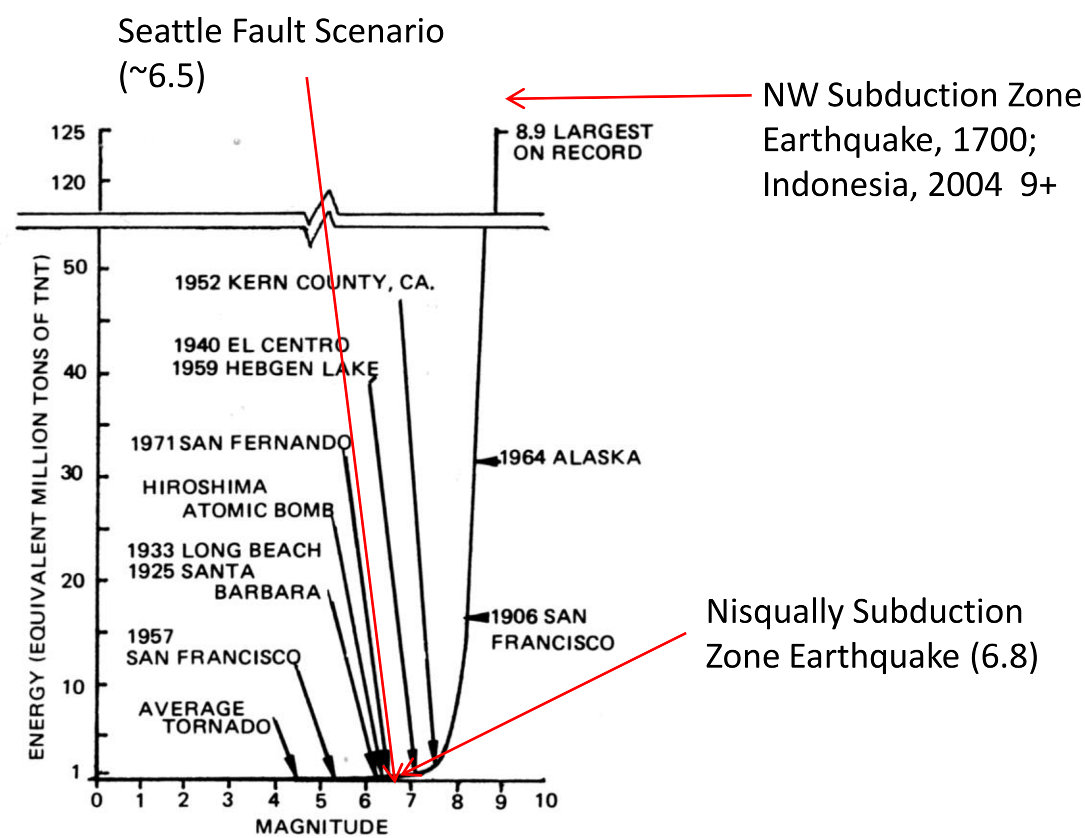
- Had One
  - Lisbon, 1755
  - San Francisco, 1906
  - Tokyo, 1923
  - Chile, 1960
  - Anchorage, 1964
- Not had one
  - Oakland/Berkeley
  - Los Angeles
  - Seattle
  - Salt Lake City

San Andreas Fault (near Ft. Tejon/Tehachapi Pass)

San Bernardino CA and Cajon Pass

Ontario CA, San Gabriel Mountains

Richter Magnitudes and Some Historic Earthquakes



This graph dramatically demonstrates the vast differences in force or energy release between moderate quakes, such as the San Fernando, and great earthquakes, such as San Francisco in 1906 and Alaska in 1964. Note the incredible span between these latter great earthquakes and the magnitude 8.9 shocks, which are the largest on record.

Peter Yanev, Peace of Mind in Earthquake Country – How to Save Your Home and Life, Chronicle Books

Richter (Energy Based) and Modified Mercalli (Descriptive) Scales

(for MM maximum damage)

Richter – One number reflecting energy release

Magnitude	Intensity (MM)	Effects
1	I	Observed only instrumentally.
2	I-II	Can be barely felt near epicenter.
3	III	Barely felt, no damage reported.
4	V	Felt a few miles from epicenter.
5	VI-VII	Causes damage.
6	VII-VIII	Moderately destructive; some severe damage.
7	IX-X	Major, destructive earthquake.
8	XI	Great earthquake.

Mercalli – Descriptive where intensity will be zoned about epicenter

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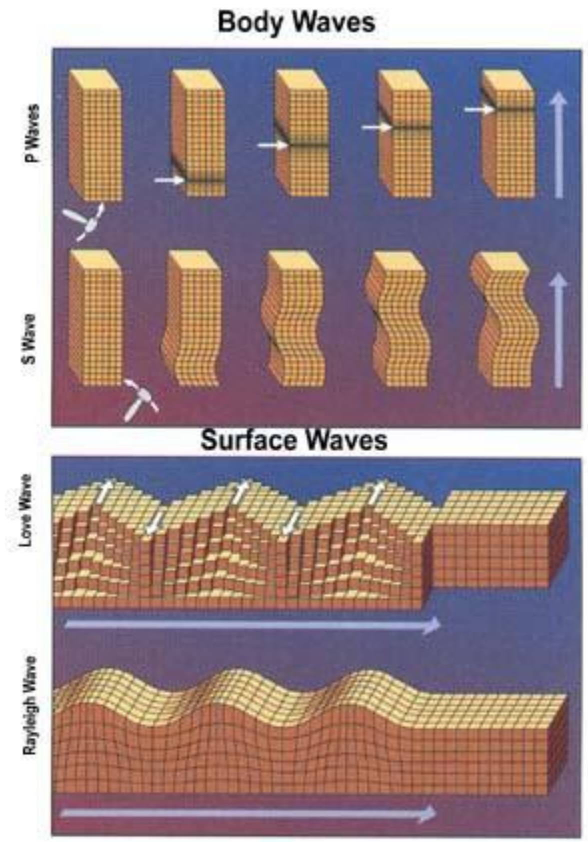
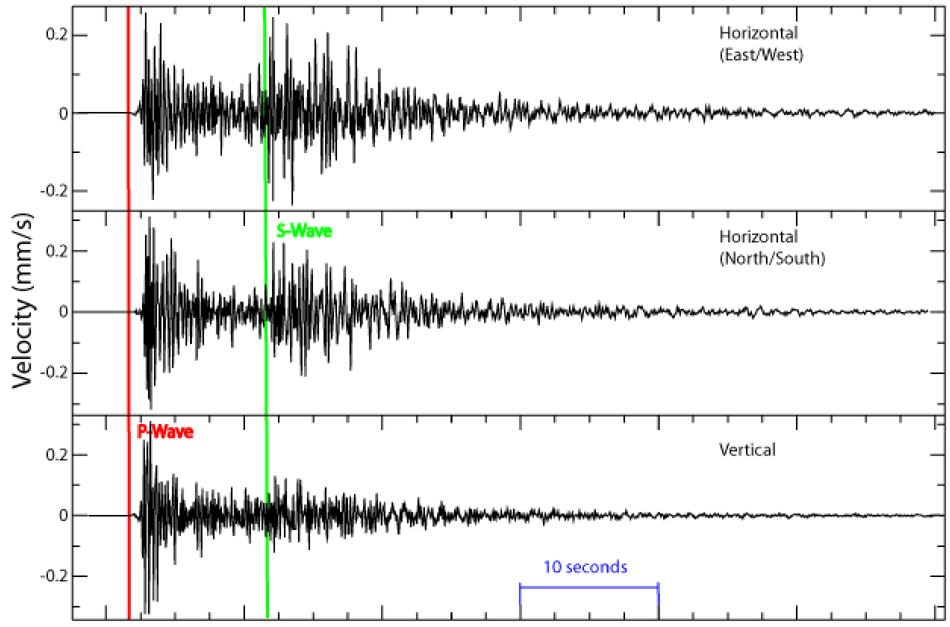
Seismic Waves



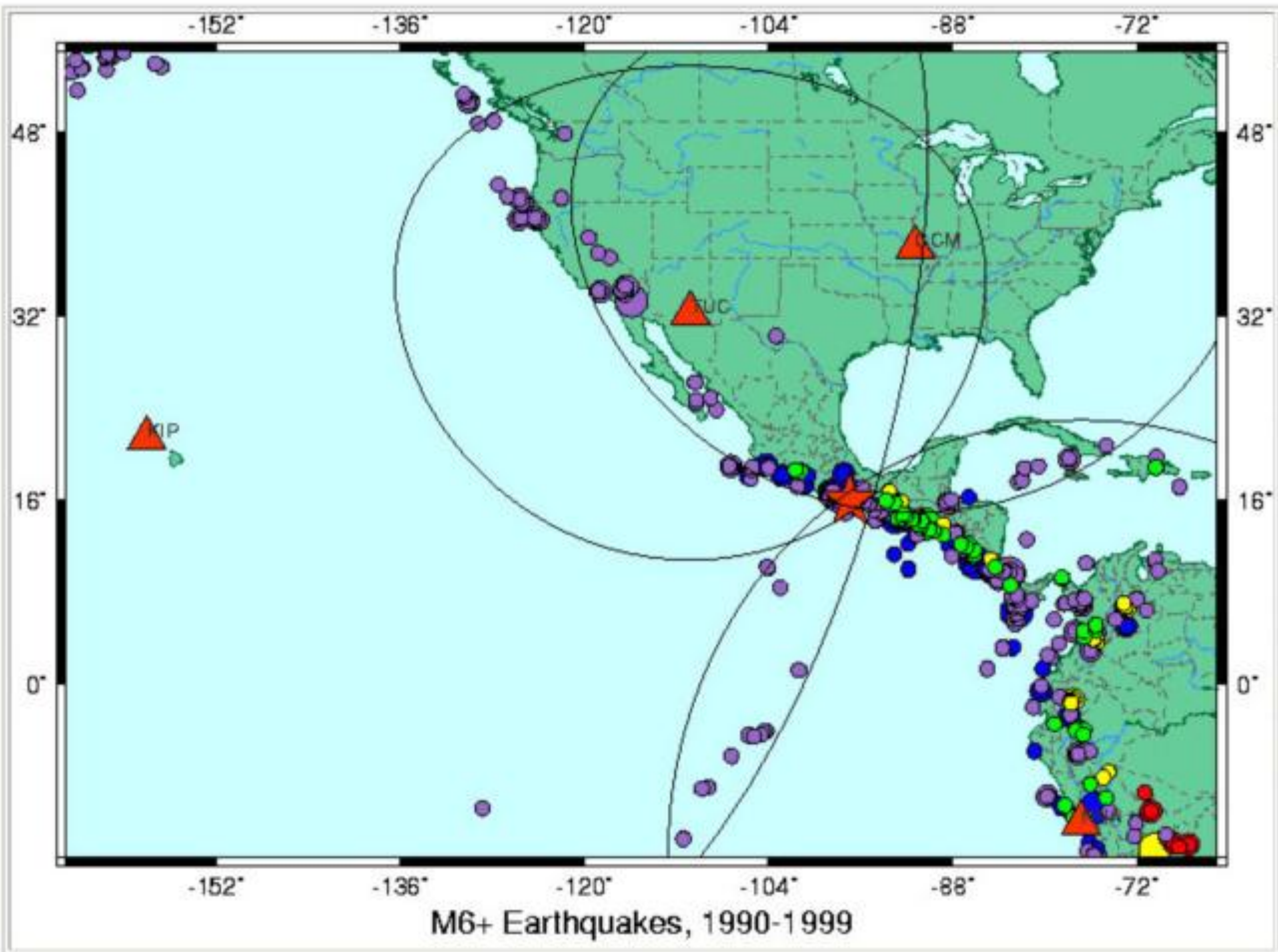


http://en.wikipedia.org/wiki/Seismic_wave

Wave Type (and names)	Particle Motion	Typical Velocity	Other Characteristics
P, **Compressional**, Primary, Longitudinal	Alternating compressions ("pushes") and dilations ("pulls") which are directed in the same direction as the wave is propagating (along the ray path)	V_P ~ 5 – 7 km/s in typical Earth's crust; >~ 8 km/s in Earth's mantle and core; ~1.5 km/s in water; ~0.3 km/s in air.	P motion travels fastest in materials, so the P-wave is the first-arriving energy on a seismogram.
S, **Shear**, Secondary, Transverse	Alternating transverse motions (perpendicular to the direction of propagation, and the ray path);	V_S ~ 3 – 4 km/s in typical Earth's crust; >~ 4.5 km/s in Earth's mantle; ~ 2.5-3.0 km/s in (solid) inner core.	S-waves do not travel through fluids, eg outer core (inferred to be primarily liquid iron) or in air or water or molten rock (magma). S waves slower than P waves in a solid
L, **Love**, Surface waves, Long waves	Transverse horizontal motion, perpendicular to the direction of propagation and generally parallel to the Earth's surface.	V_L ~ 2.0 - 4.4 km/s in the Earth depending on frequency of the propagating wave, and therefore the depth of penetration of the waves. In general, the Love waves travel slightly faster than the Rayleigh waves.	Love waves exist because of the Earth's surface. They are largest at the surface and decrease in amplitude with depth.
R, **Rayleigh**, Surface waves, Long waves, Ground roll	Motion is both in the direction of propagation and perpendicular (in a vertical plane), and "phased" so that the motion is generally elliptical – either prograde or retrograde.	V_R ~ 2.0 - 4.2 km/s in the Earth depending on frequency of the propagating wave, and therefore the depth of penetration of the waves.	Rayleigh waves decrease with depth in the Earth. Appearance and particle motion are similar to water waves.

Modified from http://web.ics.purdue.edu/~braile/edumod/waves/WaveDemo.htm

Earthquake Location



M6+ Earthquakes, 1990-1999

Use knowledge of P-S velocities and difference of arrival times to calculate distance from seismic monitoring station (corrected for depth velocity variations) .

Using multiple stations determine location.

http://web.ics.purdue.edu/~braile/edumod/as1lessons/EQlocation/EQlocation.htm

Finding Faults – Seismic Reflection

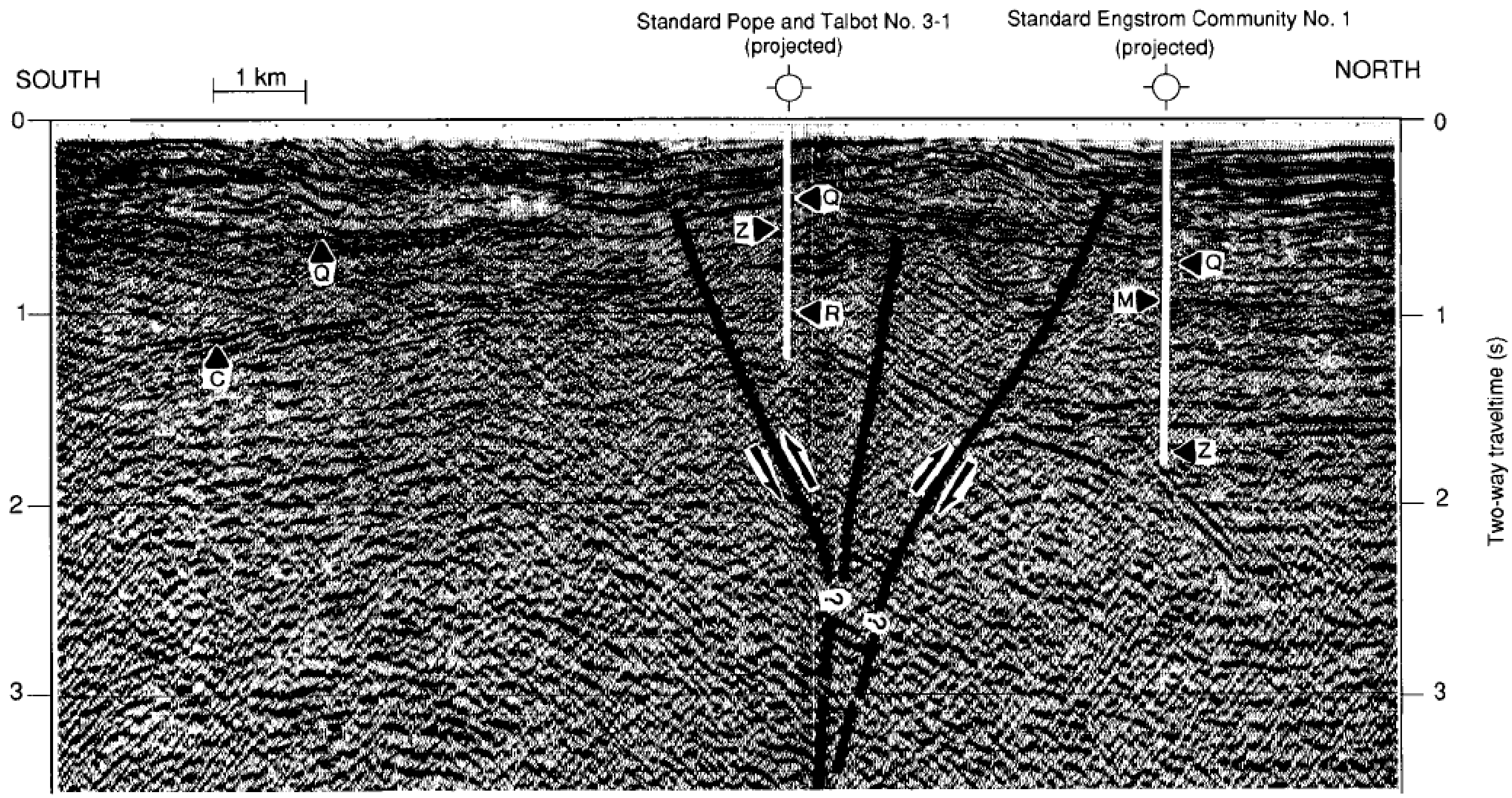
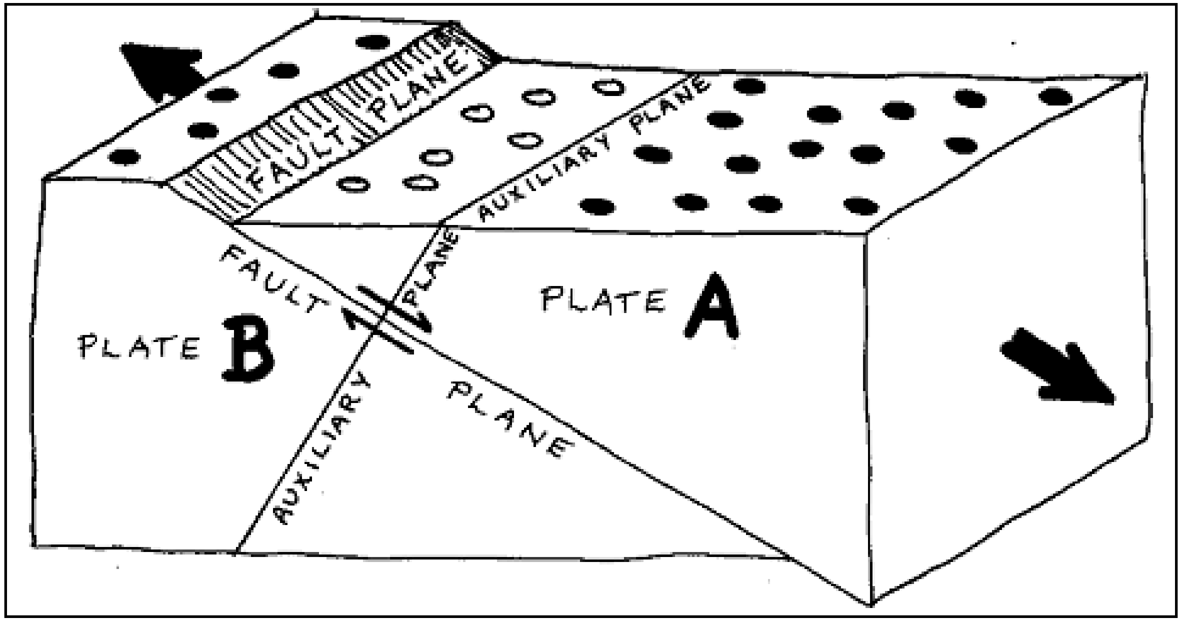


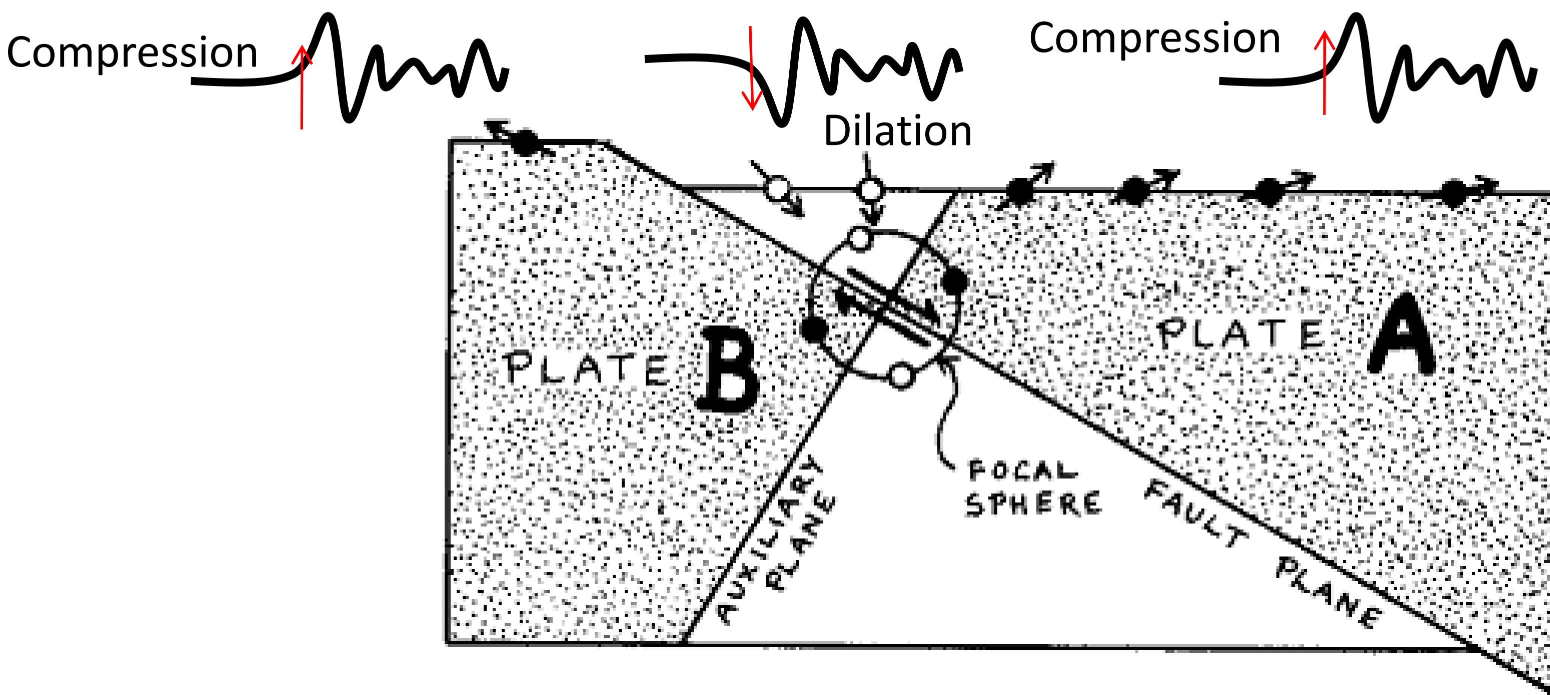
Figure 12. North-south seismic-reflection profile (migrated) on west side of Whidbey Island (Fig. 2). Arrows indicate base of Quaternary strata (Q) and stratigraphic picks in Standard Engstrom Community No. 1 and Pope and Talbot No. 3-1 boreholes: M = base of Miocene(?) section; Z = base of Zemorrian section; R = base of Refugian section. Boreholes are projected westward ≈3–4 km onto the profile from Whidbey Island. Vertical exaggeration is ≈1.5:1 at depths of 1–3 km (≈1–2.3 s TWT) based on velocities reported by Johnson et al. (1994, Fig. 5) from the Standard Engstrom (Fig. 4) borehole. Faults are inferred to have experienced both vertical offset (indicated by arrows) and lateral offset.

Samuel Y. Johnson, Christopher J. Potter, John J. Miller, John M. Armentrout, Carol Finn and Craig S. Weaver The southern Whidbey Island fault: An active structure in the Puget Lowland, Washington, Geological Society of America Bulletin 1996;108;334-354

Focal Plane Solutions for Earthquakes

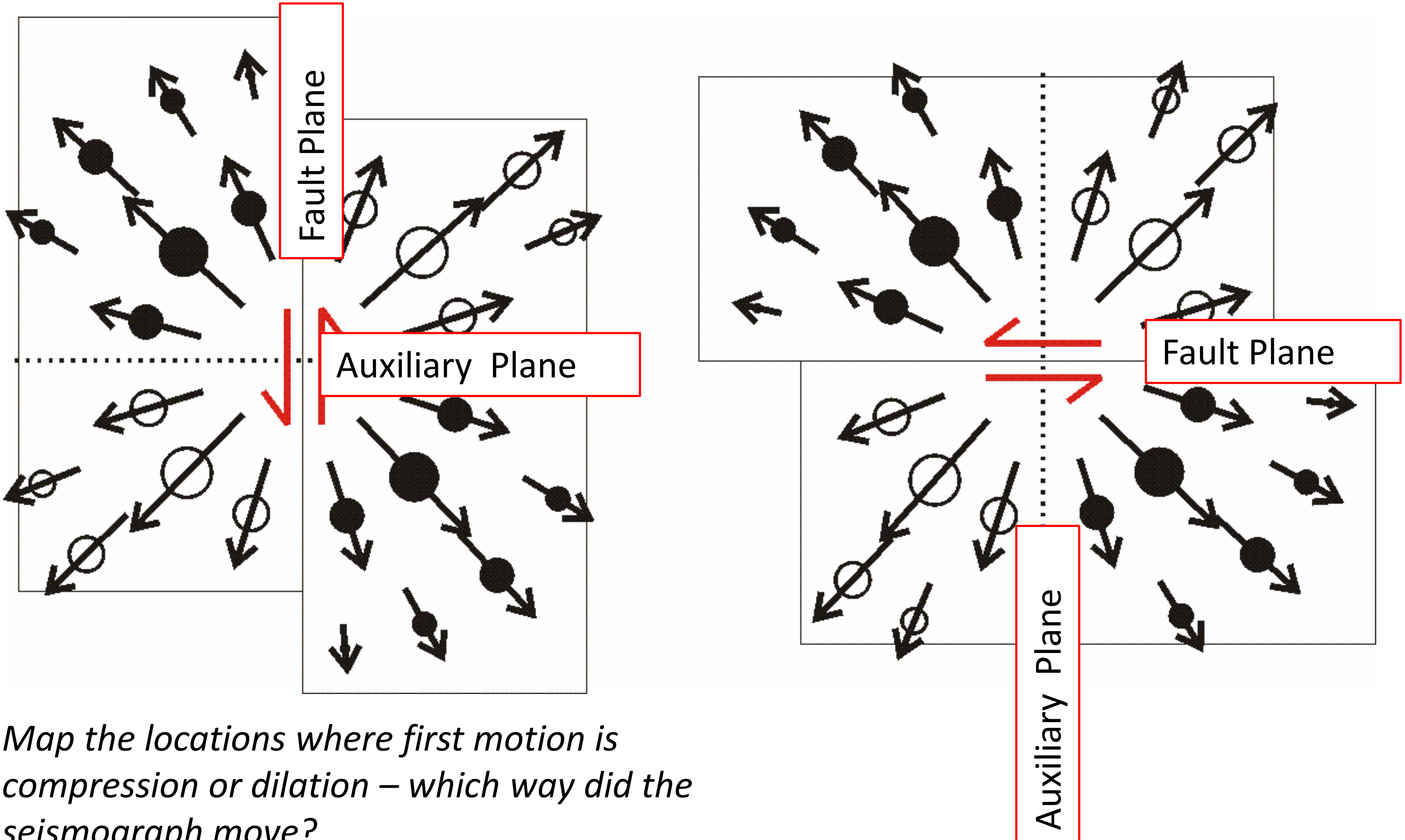
- Very important for defining faults and stresses based on earthquakes of all detectable magnitudes
- Map first motions and plot on maps and in 3-D
- Stereonet“Beach Ball” Plots





*nctr.pmel.noaa.gov/education/ITTI/**seismic/Focal**_mech_USGS.ppt*

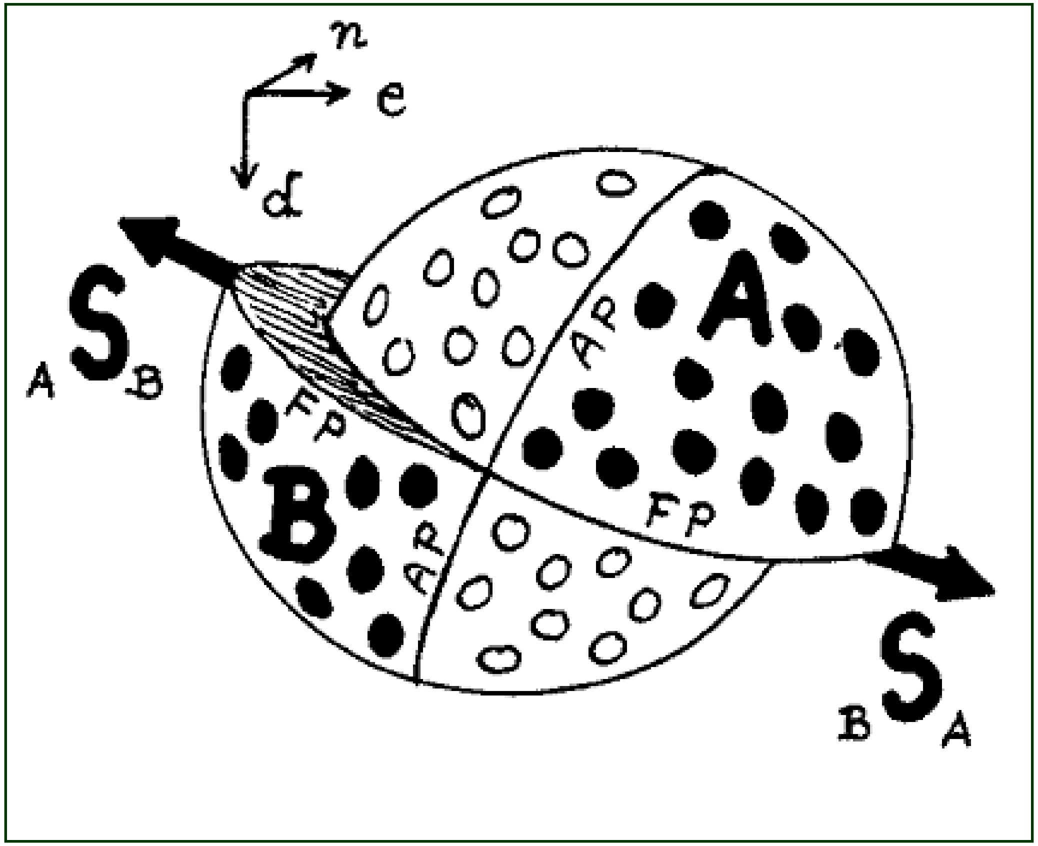
Motions define 2 planes – one is the fault; the other is not (auxiliary plane) -

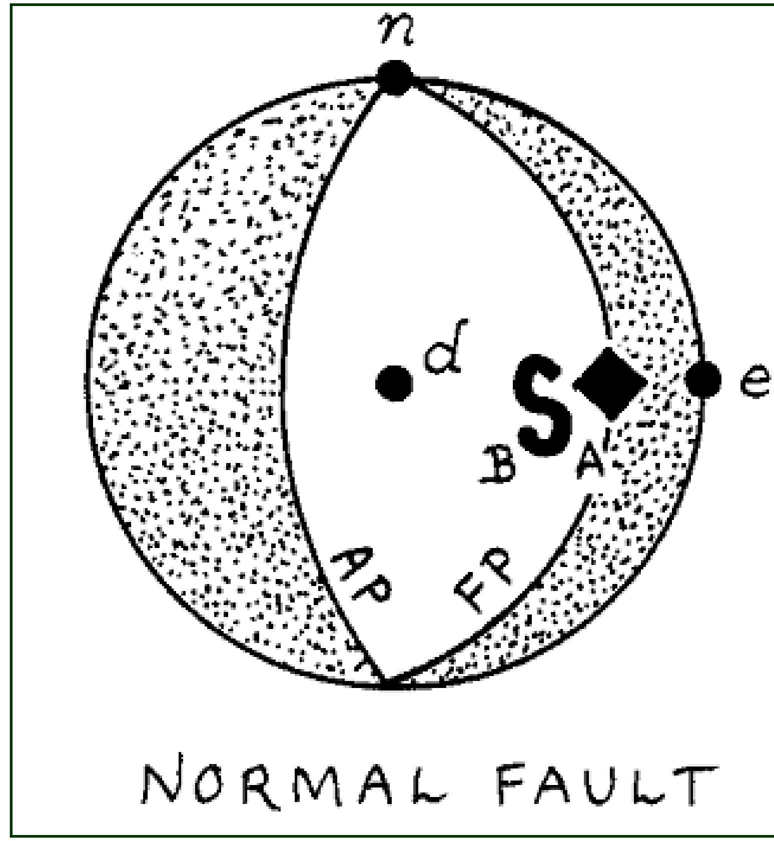


Map the locations where first motion is compression or dilation – which way did the seismograph move?

*nctr.pmel.noaa.gov/education/ITTI/**seismic**/**Focal**_mech_USGS.ppt*

With a lot of recordings we can reconstruct faults with any orientations -- Do this in 3D and plot compression vs dilation on a stereonet!





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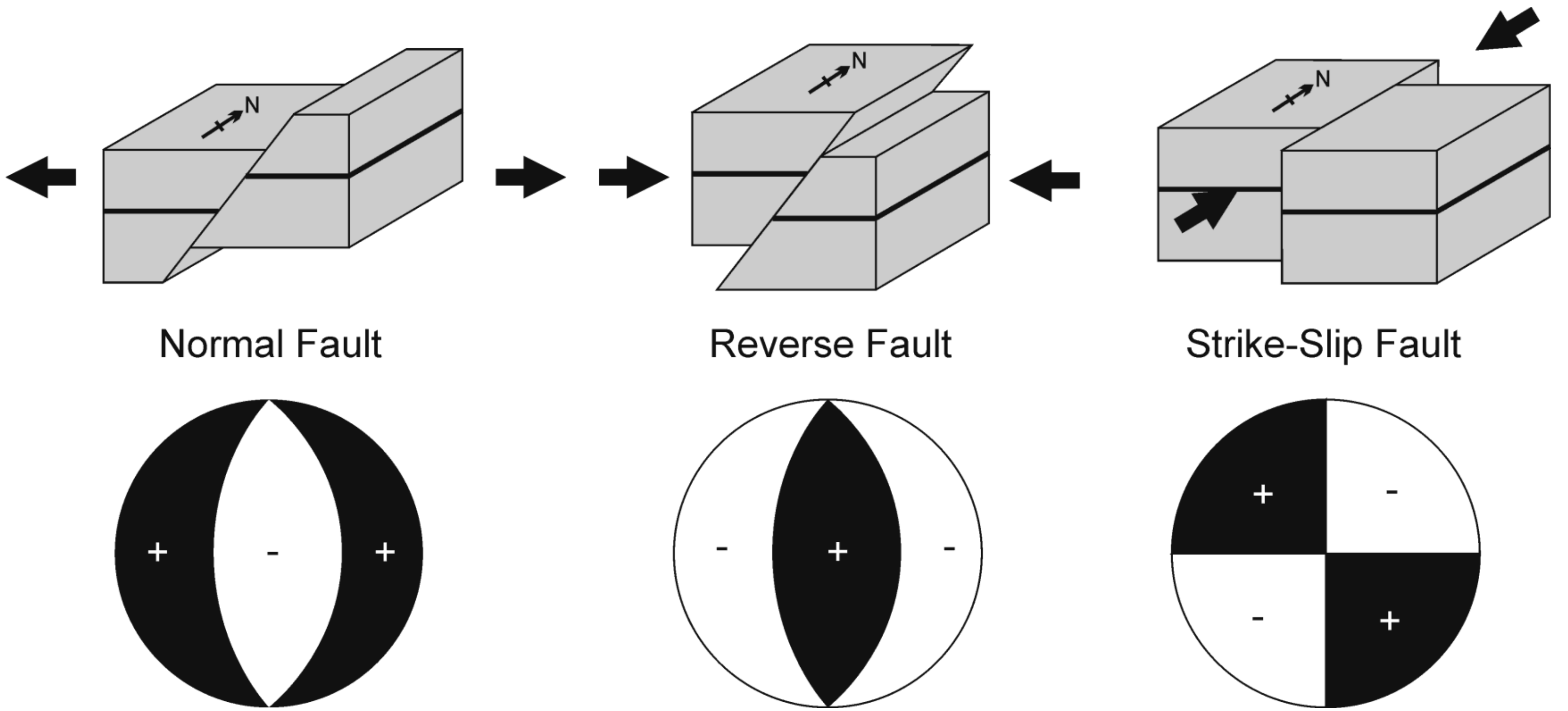
Fault types and “Beach Ball” plots



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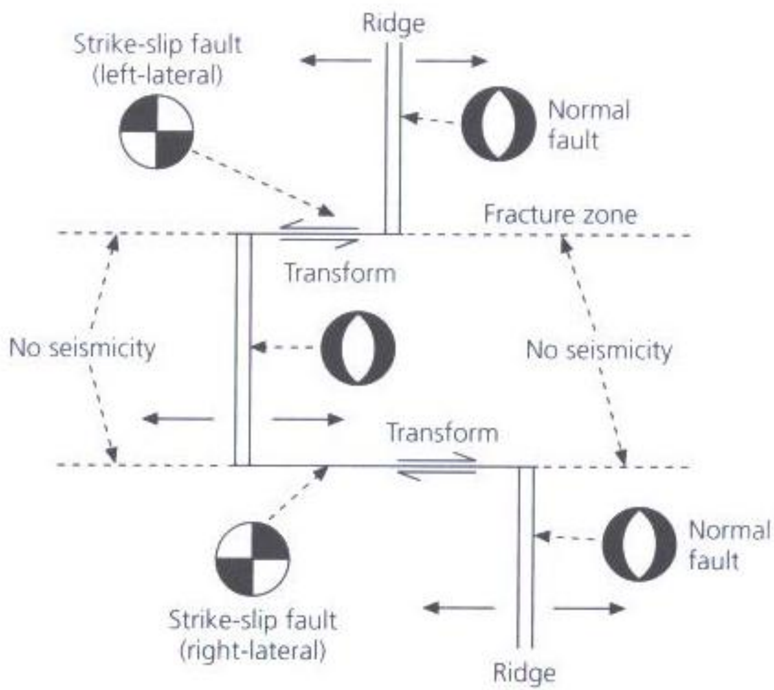
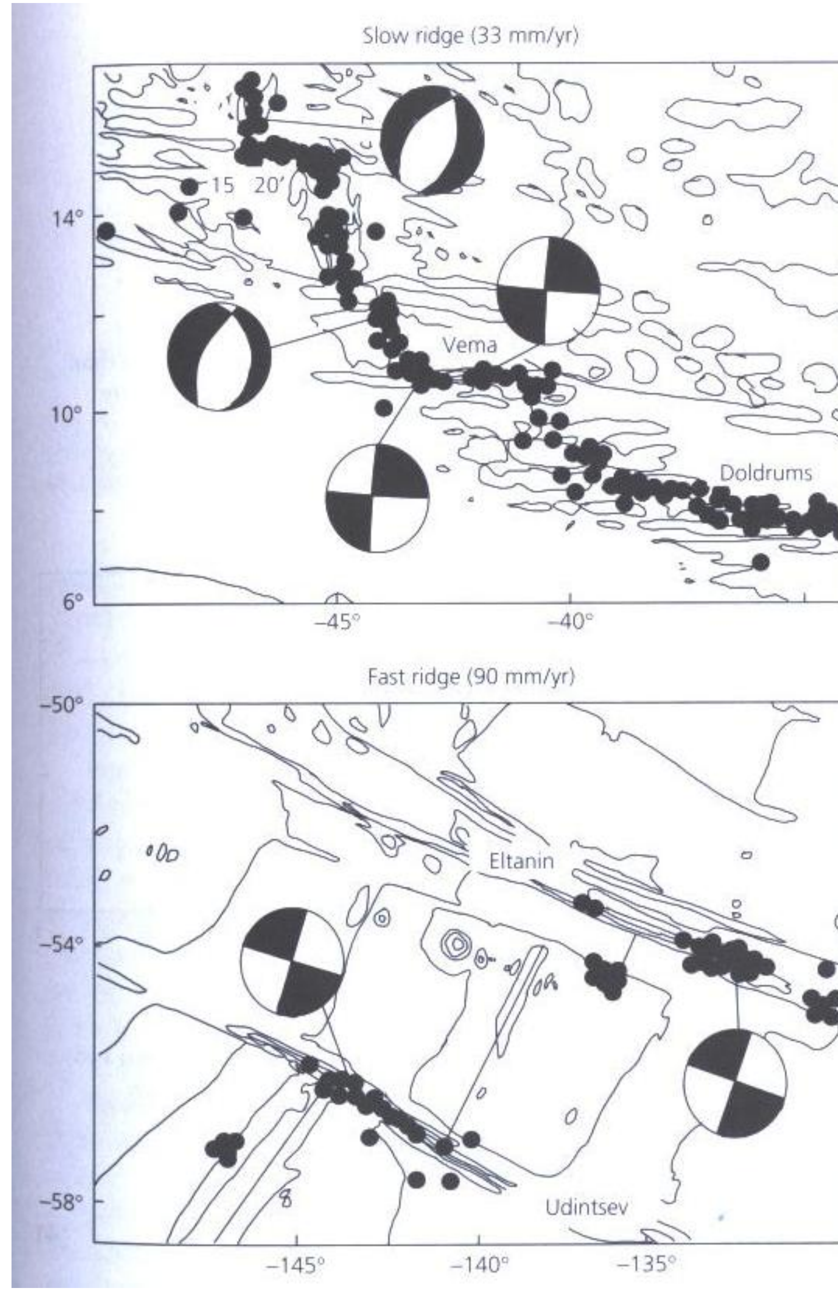
Example Focal mechanism diagrams on mid-ocean ridges





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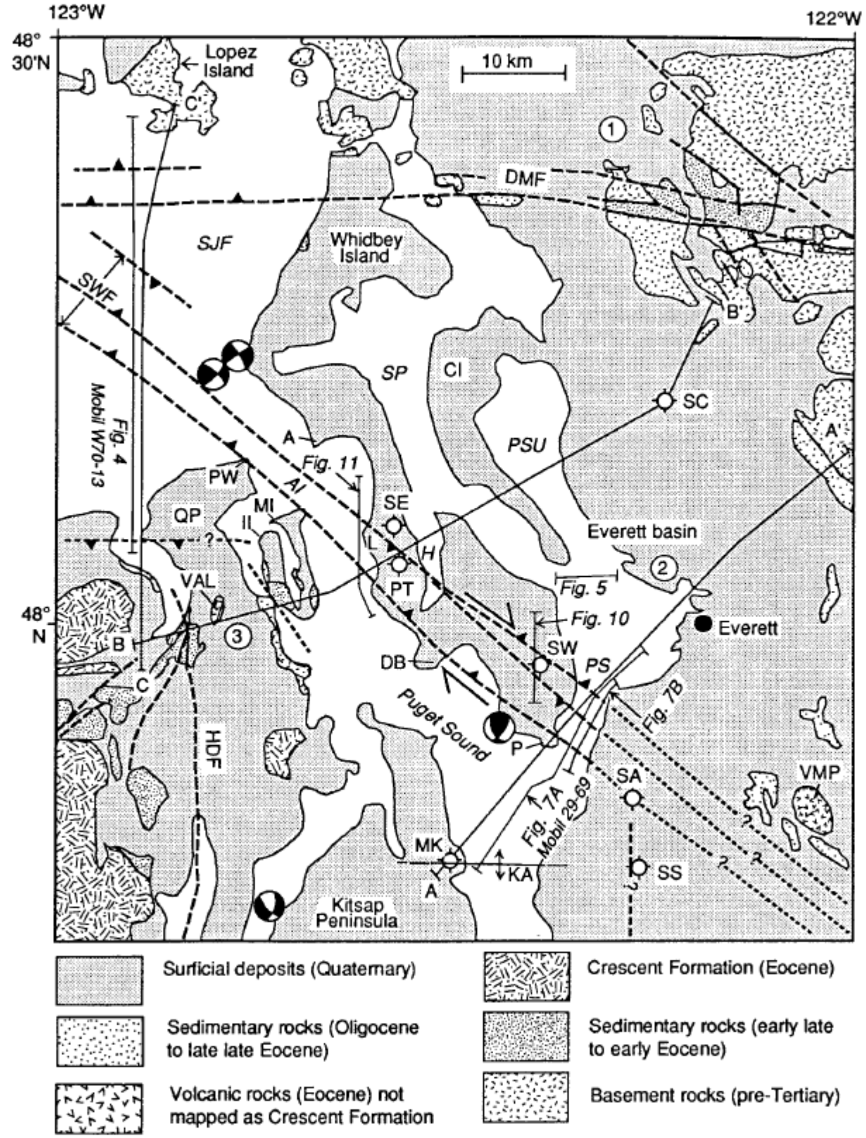
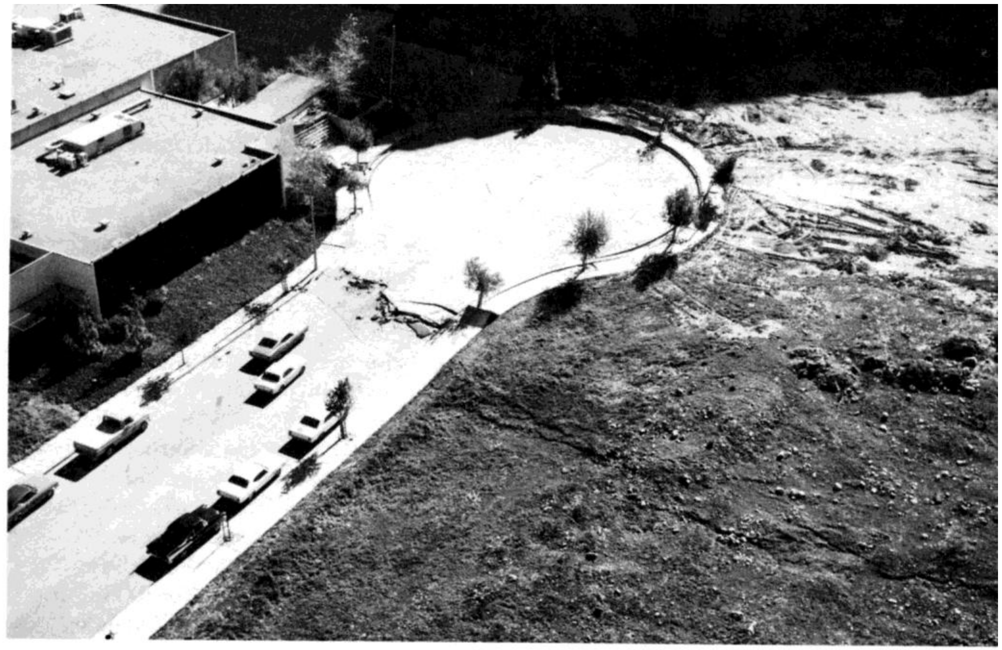
South Whidbey Island Fault



Samuel Y. Johnson, Christopher J. Potter, John J. Miller, John M. Armentrout, Carol Finn and Craig S. Weaver The southern Whidbey Island fault: An active structure in the Puget Lowland, Washington, Geological Society of America Bulletin 1996;108;334-354

Fault Rupture



The line of faulting accompanying the 1971 San Fernando earthquake just caught the right-hand corner of the building, breaking the stairway. The land across the street is now developed and the traces of the fault are covered until the next earthquake on the fault leaves a path of damaged buildings. As a home owner or home buyer in an area crossed by a fault, you cannot rely on the inadequate zoning ordinances of a city or county or the honesty or knowledge of a developer. You must procure the available detailed fault maps of the area and establish for yourself the proximity of faults and faulting to your property.

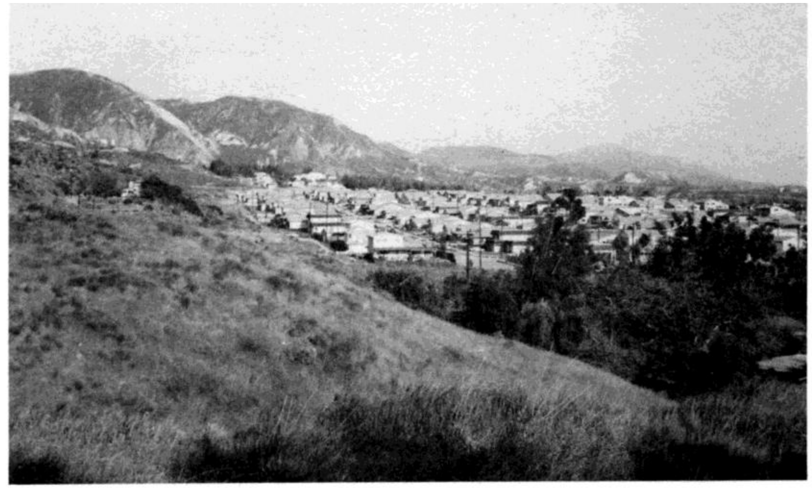
Peter Yanev, Peace of Mind in Earthquake Country – How to Save Your Home and Life, Chronicle Books

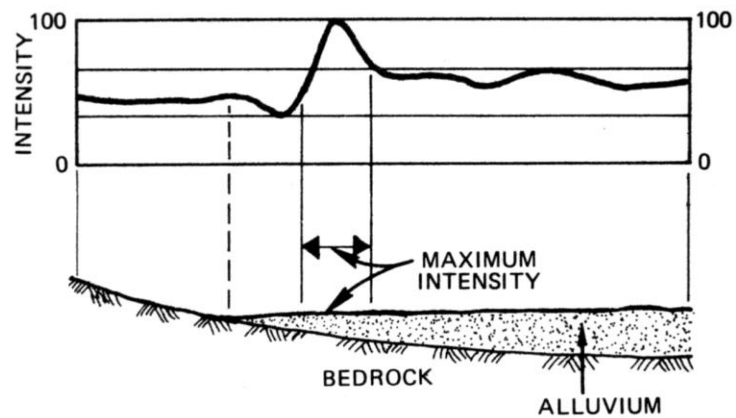
Fault Rupture

A vertically moving, or thrust fault left this tall scarp in the rock and soil along the fault near Dixie Valley, Nevada, in 1954. Note that the wood-frame shack within the fault zone but removed by several feet from the fault trace survived the heavy shock waves of the quake with no apparent damage. If the structure had been directly astride the fault, it would be a pile of broken lumber.

Peter Yanev, Peace of Mind in Earthquake Country – How to Save Your Home and Life, Chronicle Books

Amplitude Effects at Interfaces



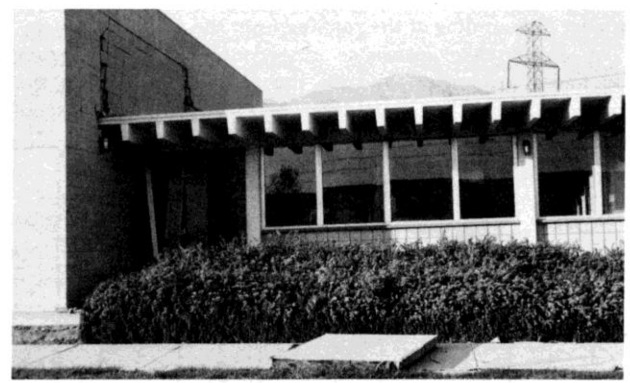


The earthquake waves rumbling through deep soil may be greatly magnified at the interface of the soil with the bedrock of a hill or mountain. Such hill-base sites are particularly susceptible to damage when a fault is nearby, as in much of the East Bay region of San Francisco Bay and in sections of the Los Angeles Basin. An example of such an area in Los Angeles is this photograph of the northeastern boundaries of Sylmar along the base of the San Gabriel Mountains. The homes here suffered the greatest damage of all the areas affected by the San Fernando quake.

Peter Yanev, Peace of Mind in Earthquake Country – How to Save Your Home and Life, Chronicle Books

"Pounding" Damage

The pounding damage to these commercial buildings in Anchorage can be seen in the cracks and shattered corner of the building on the right as well as the extensive damage to the facing and windows all along the adjoining wall of the other building. Pounding damage occurs because adjoining buildings respond with different movement to the shock waves of an earthquake. Row houses with varying roof lines are also subject to this type of damage.



The damage to the concrete-block wall of this building in San Fernando Valley was caused by pounding from the adjacent lower roofline. Such pounding damage can be avoided or minimized if the wall adjacent to a lower roofline of the same or a separate building is stiffened with horizontal beams or with a floor slab located in the same building. This gap can then be partially filled with a protective crumple-section joint of thick stucco, neoprene or other material.

Peter Yanev, Peace of Mind in Earthquake Country – How to Save Your Home and Life, Chronicle Books