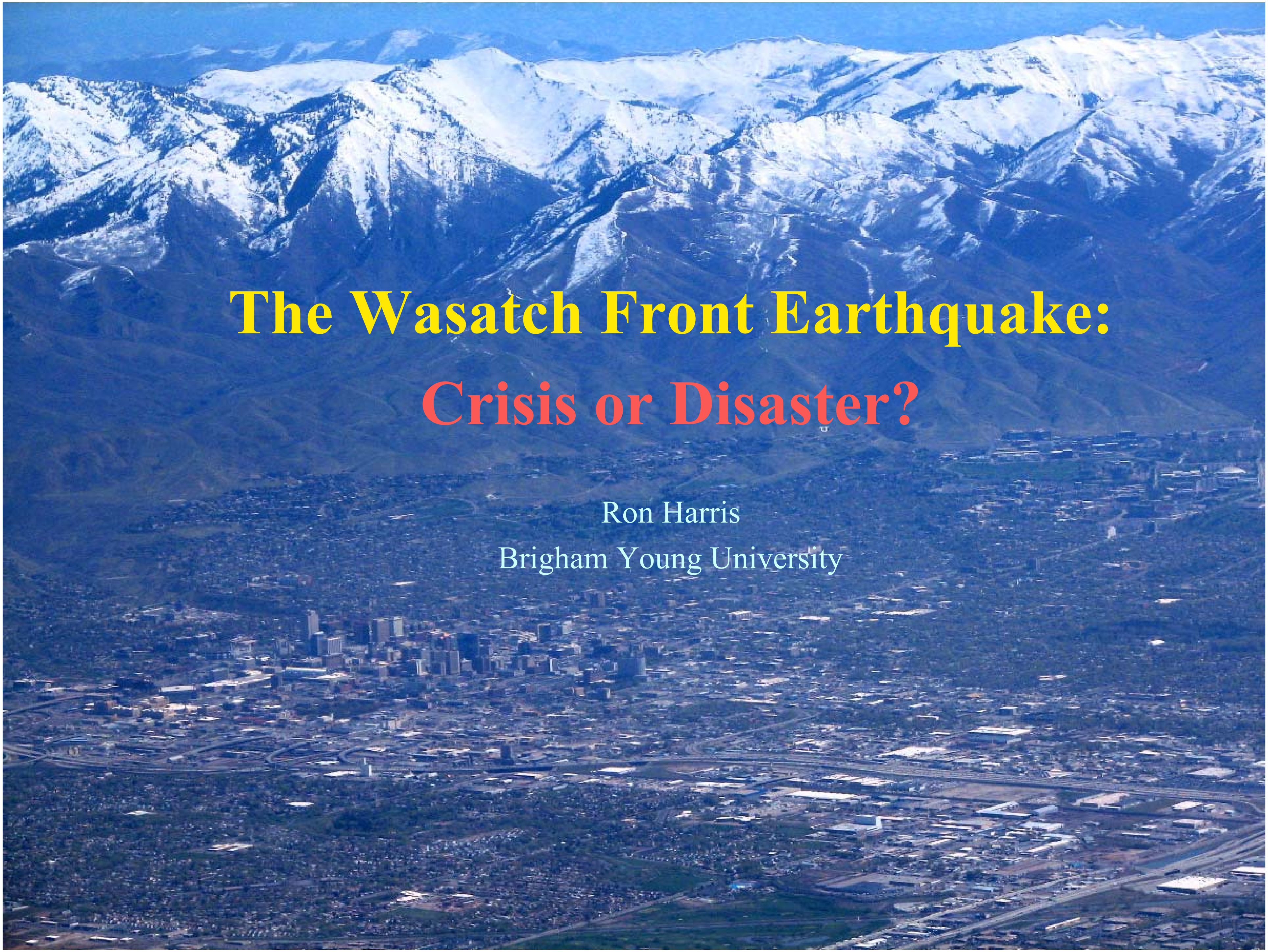
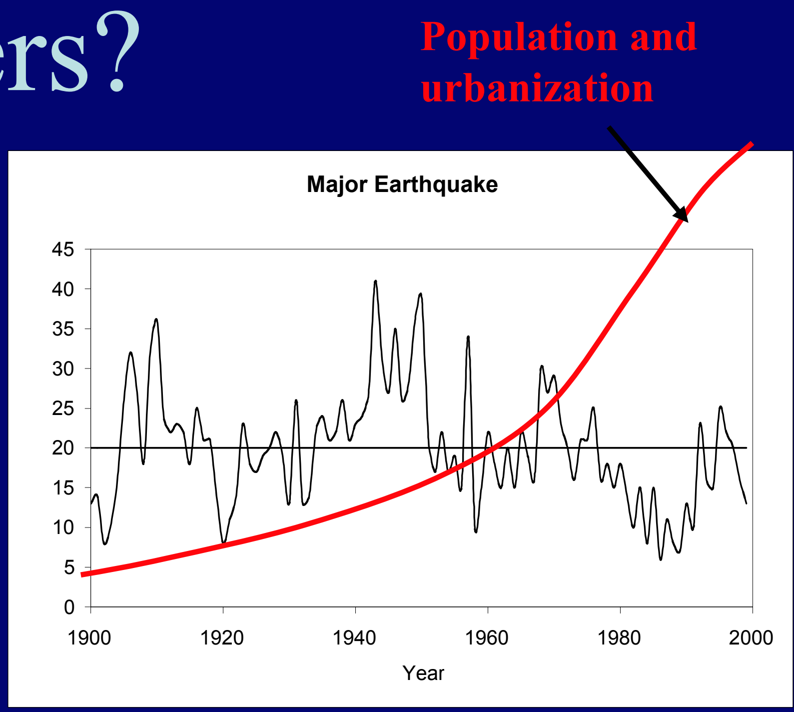


The Wasatch Front Earthquake:
Crisis or Disaster?

Ron Harris
Brigham Young University

Why so many Disasters?



• $52 billion per year cost to US

• 1994 Northridge Earthquake (M = 6.7)
- Economic loss of $49 billion
- 20,000 plus people homeless
- Damaged up to 1,000 buildings
- Major Transportation Infrastructure Destruction
- Aggregate Business Losses nearly $6 billion
-Business Physical Damage: 57%

• Kobe, Japan (M = 6.9)
-$200 billion in damages
- 200,000 dwellings and buildings damaged
- 350,000 homeless

"Too often we bask in our comfortable complacency and rationalize that the ravages of war, economic disaster, famine, and *earthquake* cannot happen here. Those who smugly think these calamities will not happen, that they somehow will be set aside because of the righteousness of the Saints, are deceived and will rue the day they harbored such a delusion."

- President Ezra Taft Benson

More People and Cities in Harms Way?

	Fatalities	Cost
Earthquakes		
• Sumatra	>250,000	12 b$
• Pakistan	> 80,000	5 b$
• Turkey	> 30,000	8.5 b$
• Kobe	5,300	200 b$
• Northridge	150	49 b$
Hurricanes		
• Katrina	1,400	150 b$
• Rita	100	5 b$

QuickTime™ and a
H.263 decompressor
are needed to see this picture.

Natural Hazards + cities = crisis
Natural Hazards + vulnerable cities = Disaster

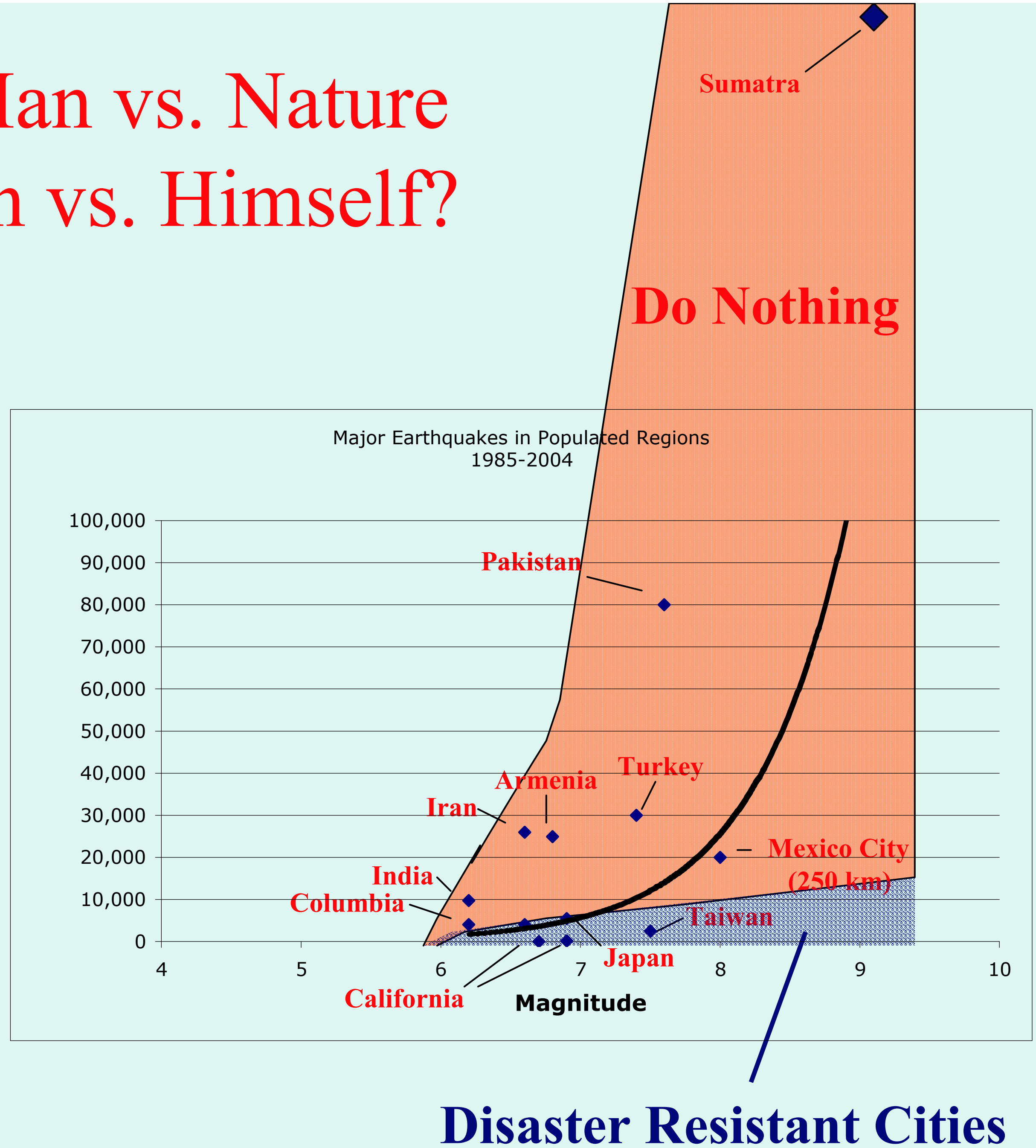
Vulnerability = Poor construction and site characteristics

Vulnerability transforms a crisis into a disaster.

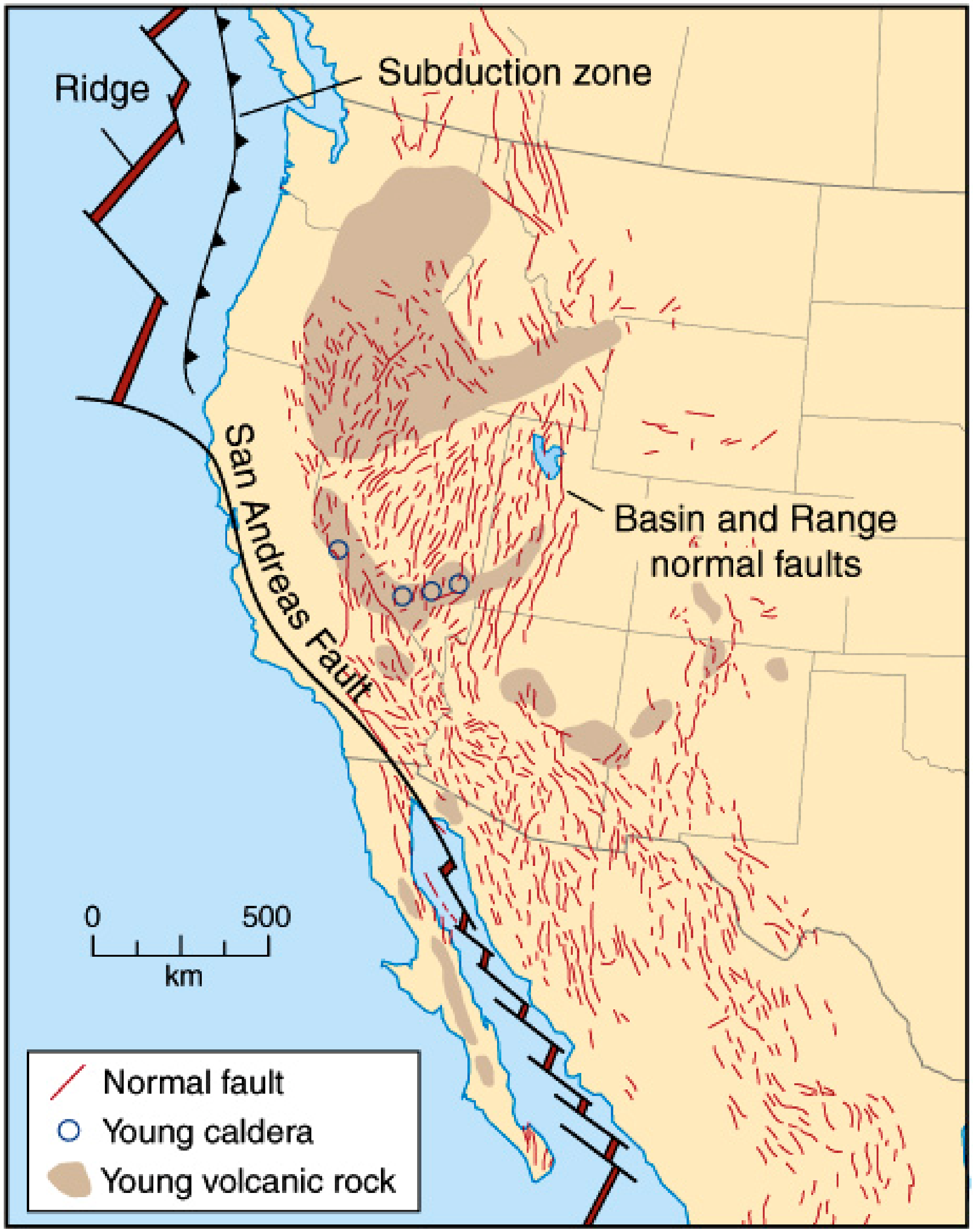
Protection =
- Education
- Preparation
- Early Warning
- Rapid Response

Is it Man vs. Nature or Man vs. Himself?

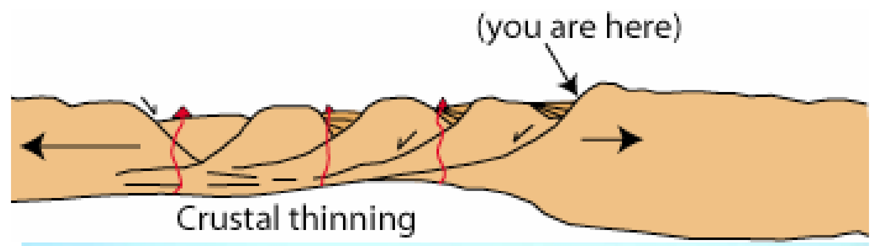
- We have the knowledge and resources to protect ourselves
- We can prepare a disaster resistant cities
- Do we have the will?

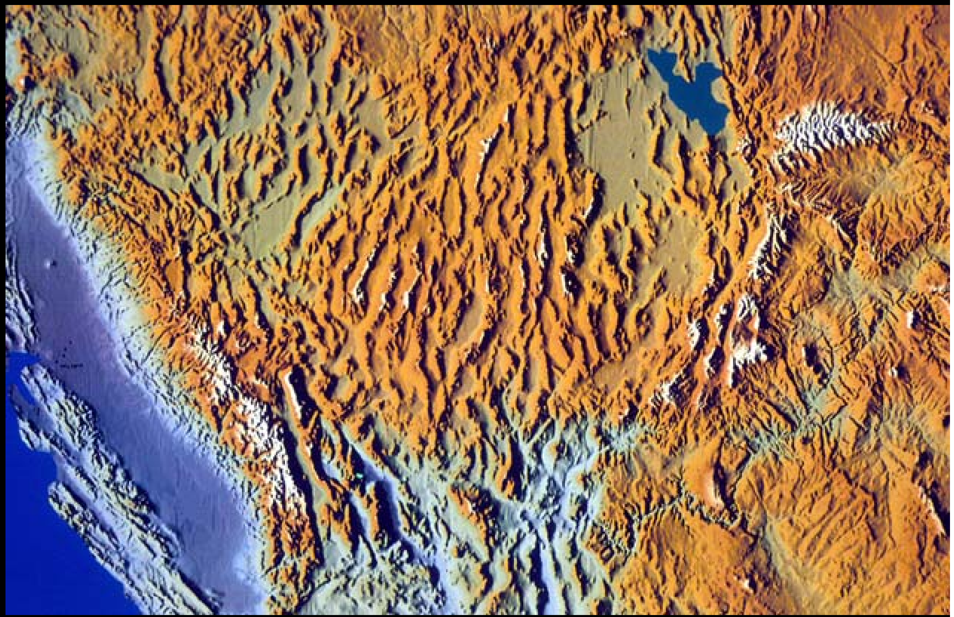


Why Earthquakes in Utah?



QuickTime™ and a Animation decompressor are needed to see this picture.

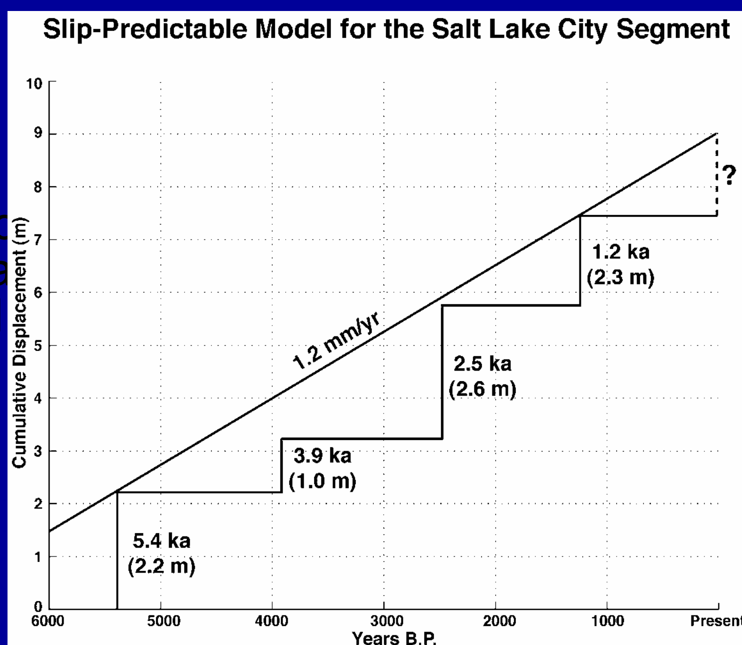


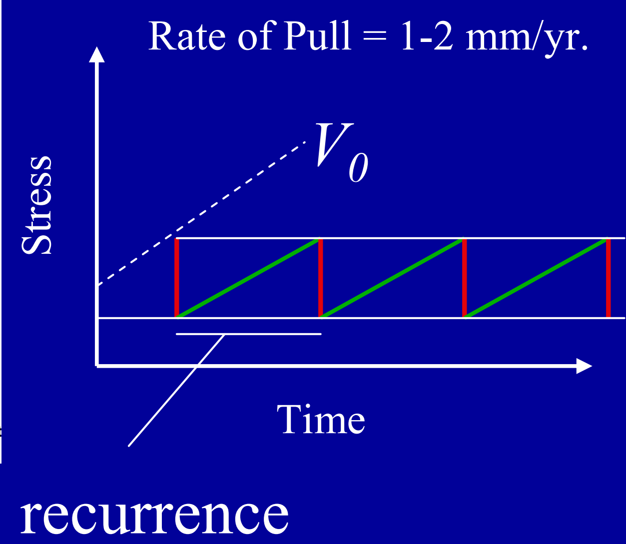


How do Earthquakes Work?

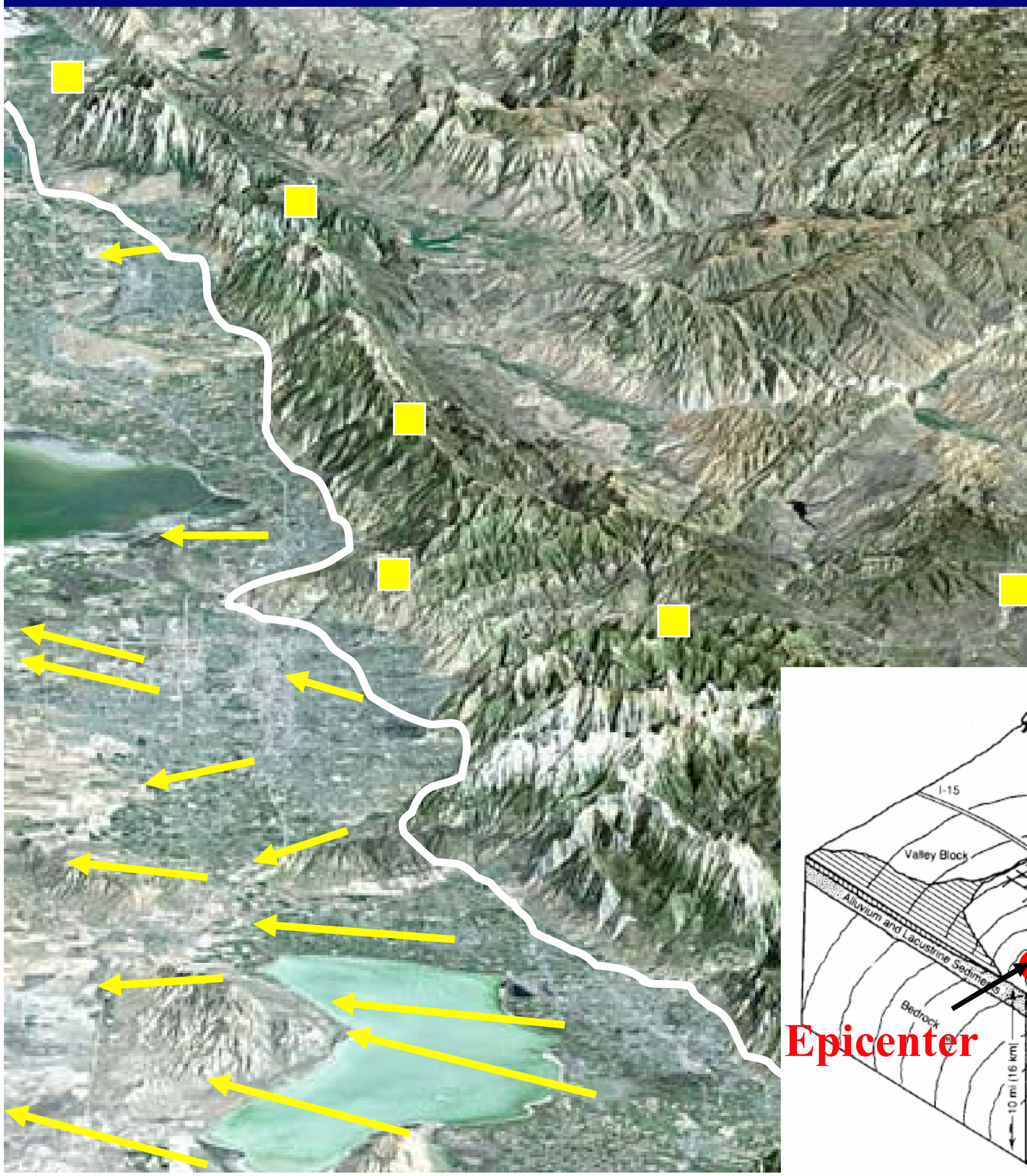
QuickTime™ and a
H.263 decompressor
are needed to see this picture.

Quic
Cinepa
are needed



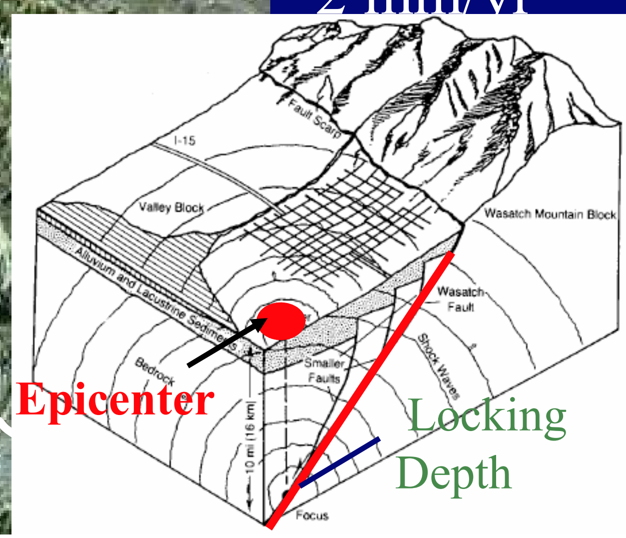


Is the Wasatch Fault Still Active?
Is the Spring Still Stretching?
If so, How Fast?



■ Little to no motion with respect to stable North America

← 2 mm/yr



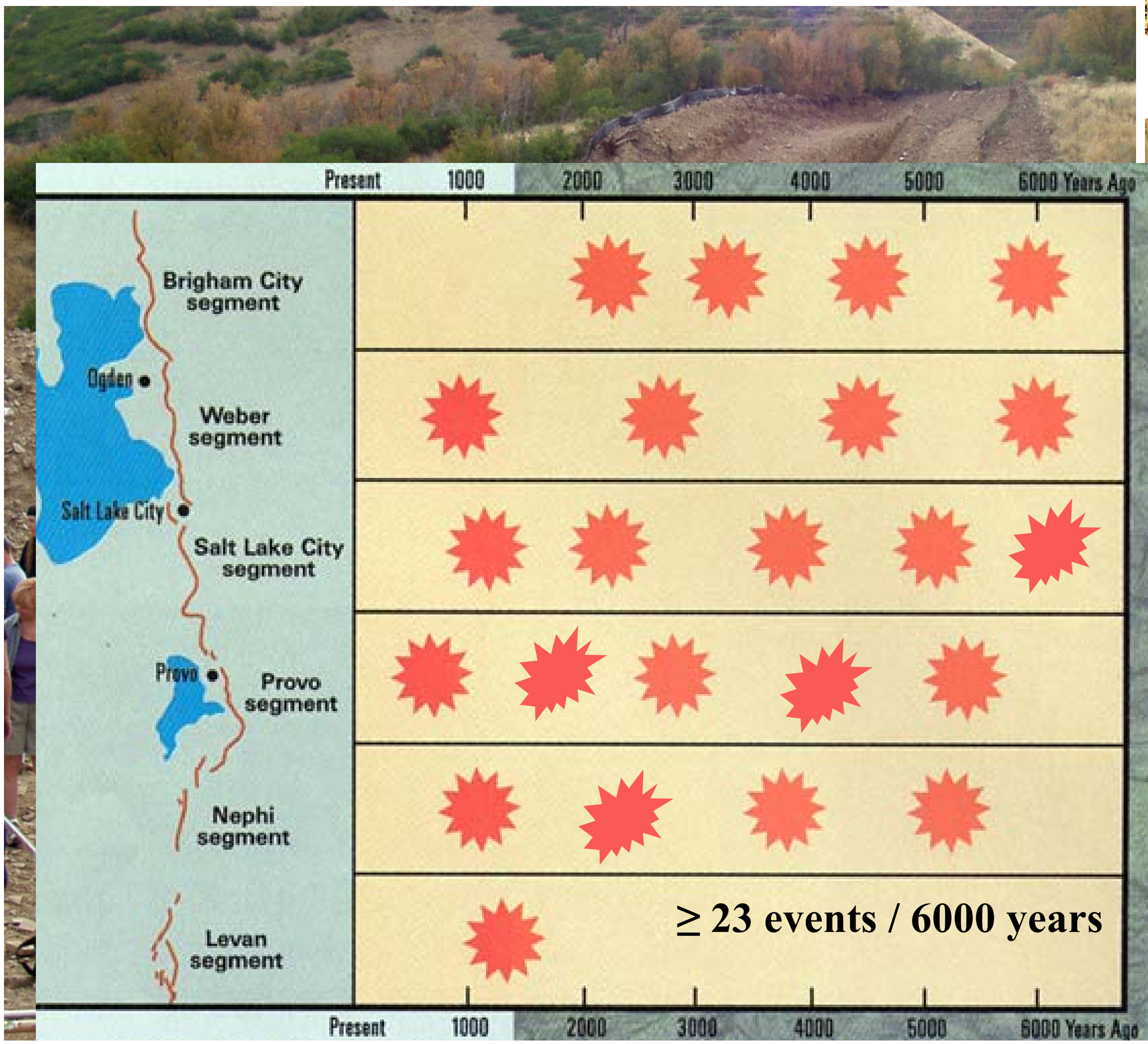
- Sites east of the fault show no movement relative to stable NA.
- Sites west of the fault show 2-3 mm/yr. westwards stretch.
- Spring is stretching at ~2-3 mm/yr.
- 1000 yrs. = 2-3 m

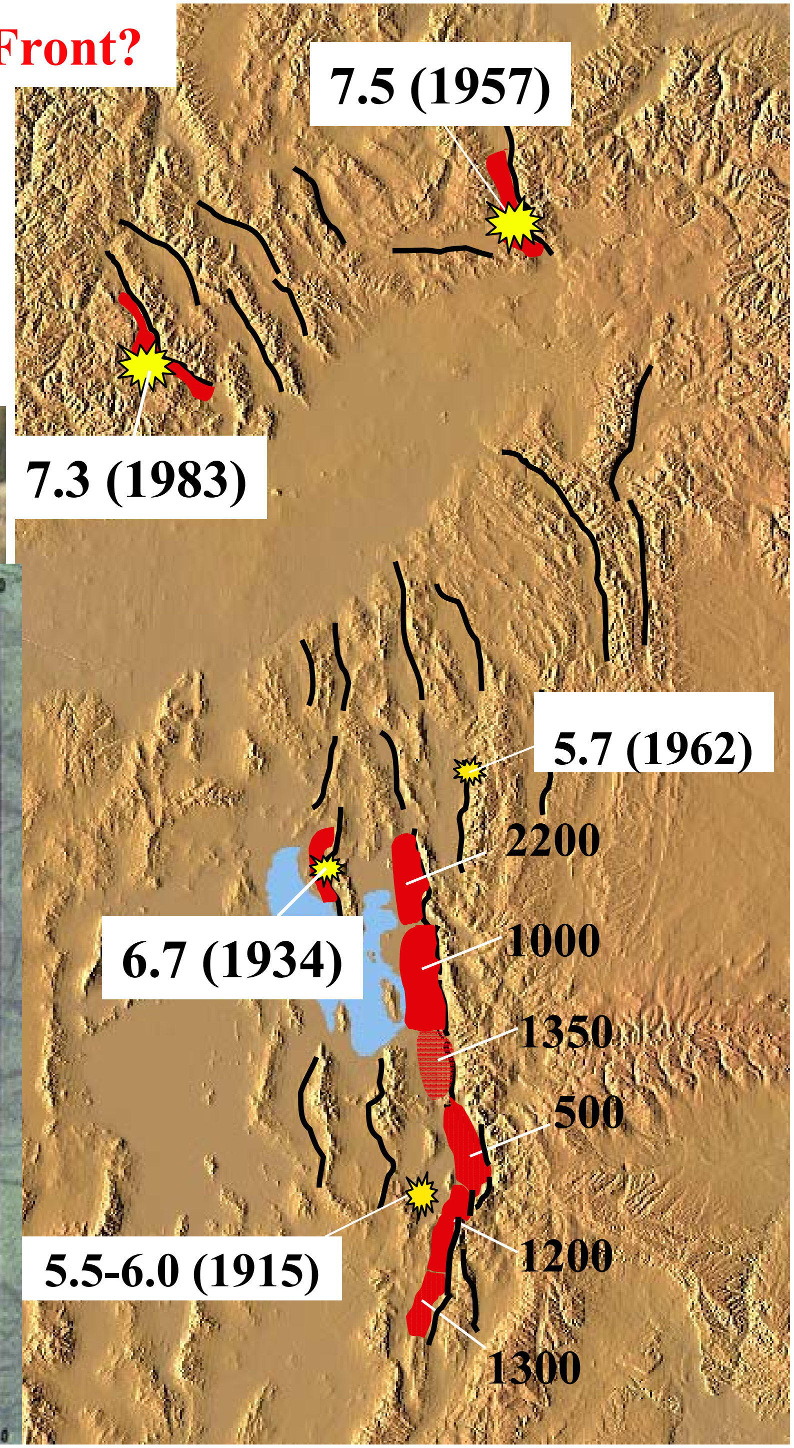
When the Energy in the ‘Spring’ is Released

QuickTime™ and a
DV/DVCPRO - NTSC decompressor
are needed to see this picture.

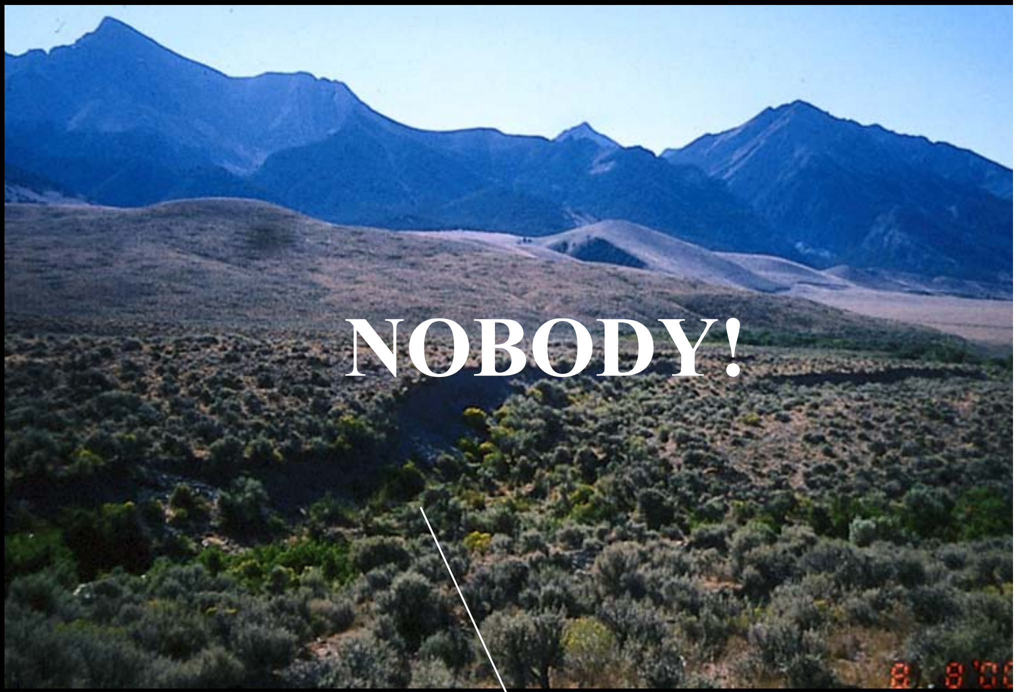
How Often Do Earthquakes Strike the Wasatch Front?

- For the Entire Wasatch Fault there is a magnitude ≥ 7.0 Earthquake a minimum of every 260 years.
- Last event was 500 years ago.
- The Salt Lake Segment last rupture 1350 years ago.





Borah Peak -1983
Foreshadow of What's Ahead?

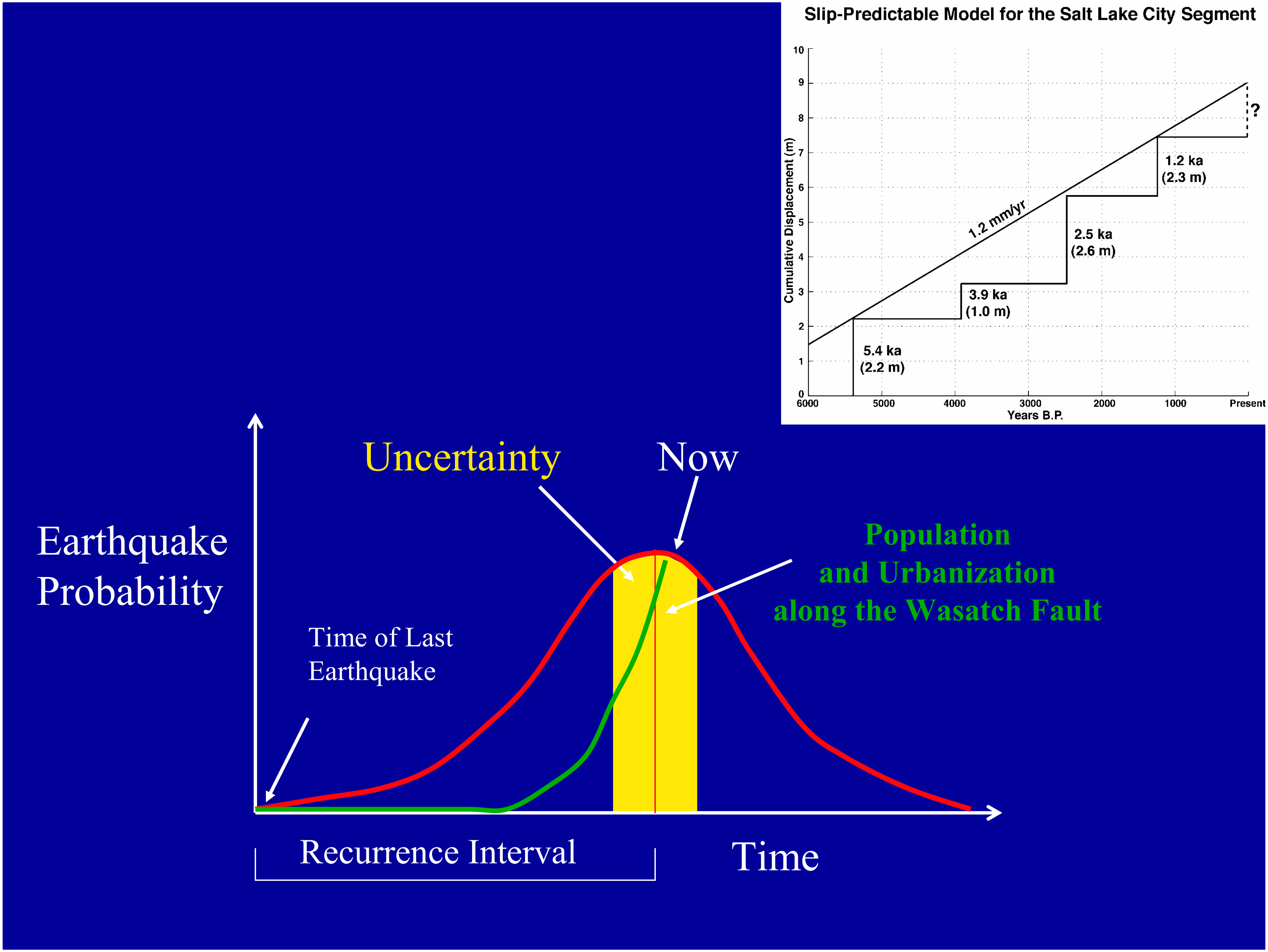


Magnitude 7.3
Earthquake (1983)
Valley dropped 2.5 m

Damage to town of Mackay,
40 miles from epicenter

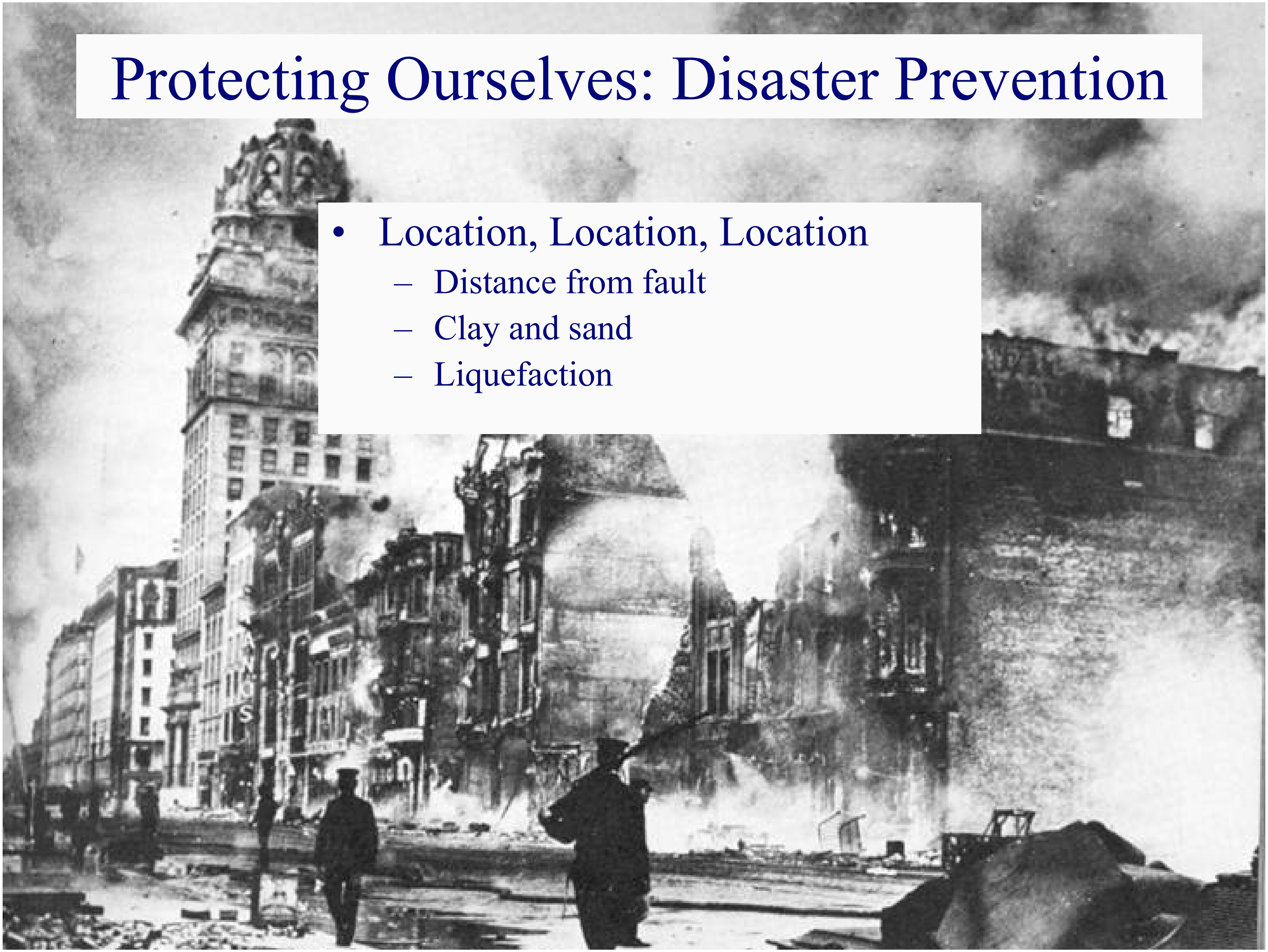
EVERYBODY!

rface Scars from Last Earthquake 1350 years
). Valley dropped 8 feet at speed of sound.



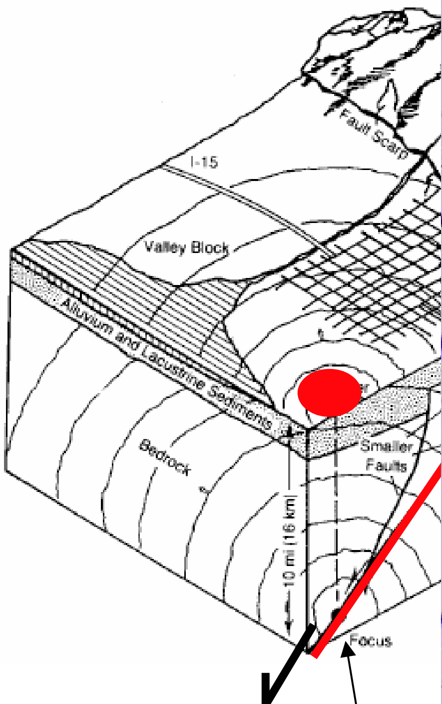
Slip-Predictable Model for the Salt Lake City Segment
Cumulative Displacement (m)
Years B.P.
6000
5000
4000
3000
2000
1000
Present
0
1
2
3
4
5
6
7
8
9
10
1.2 mm/yr
5.4 ka
(2.2 m)
3.9 ka
(1.0 m)
2.5 ka
(2.6 m)
1.2 ka
(2.3 m)
?
Uncertainty
Now
Earthquake
Probability
Population
and Urbanization
along the Wasatch Fault
Time of Last
Earthquake
Recurrence Interval
Time

Protecting Ourselves: Disaster Prevention

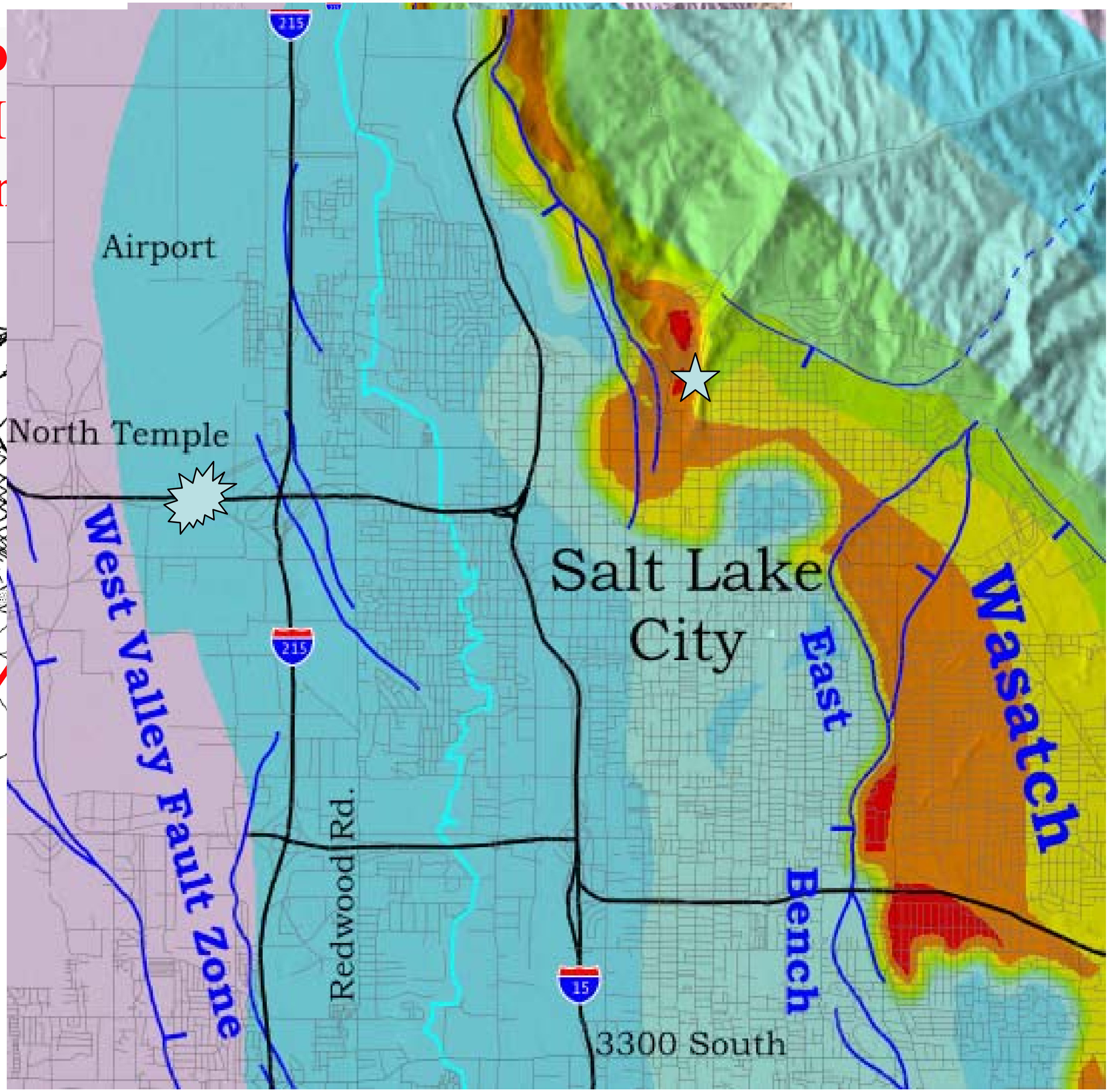


- Location, Location, Location
  - Distance from fault
  - Clay and sand
  - Liquefaction

Distance fro
Epicenter: H
Much Shakin



Locking Depth
(10 miles)



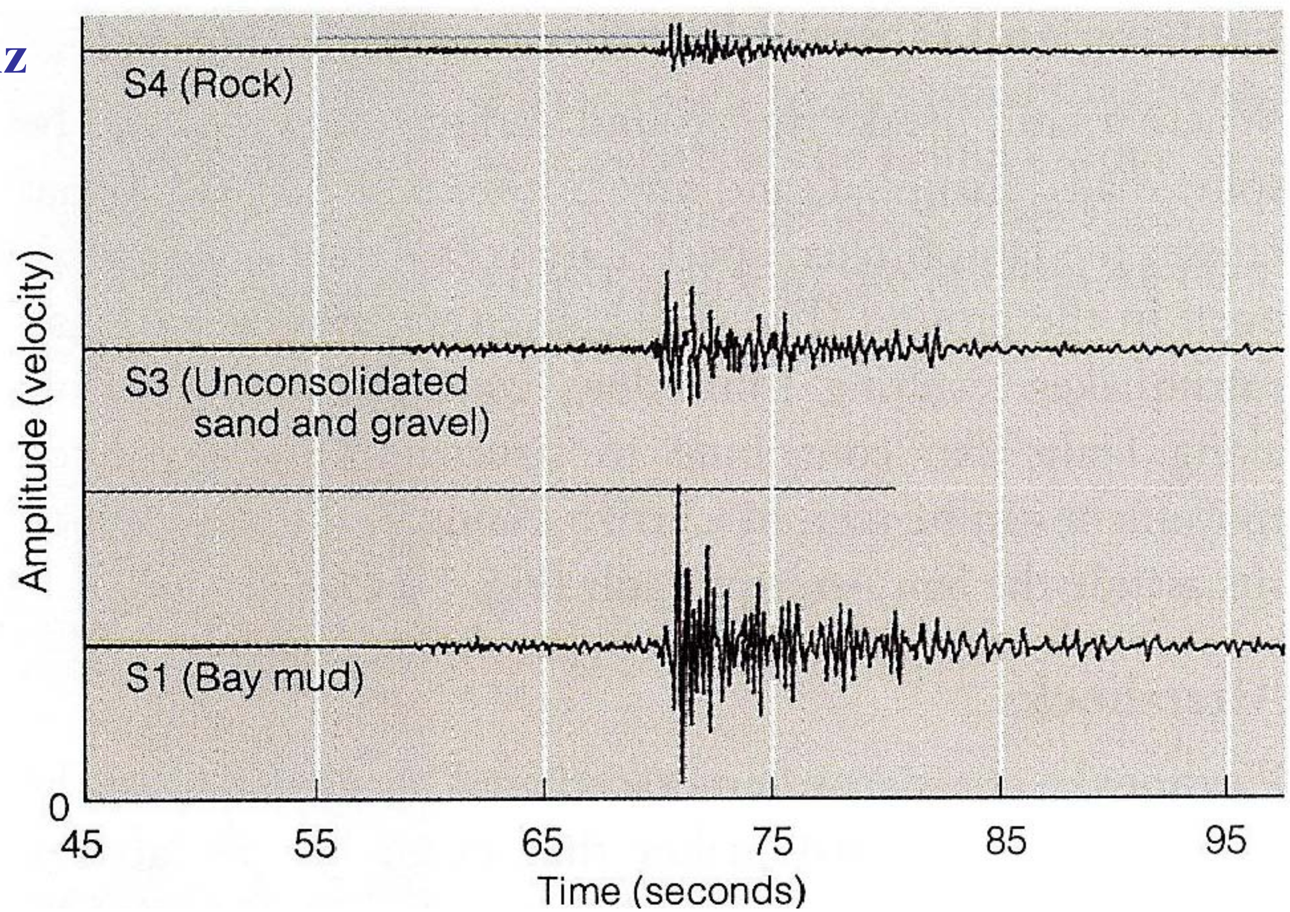
"The Foolish Man Built His House (City) Upon the Sand!"

Acapulco, Santa Cruz
- **nearer to epicenter**
- **little damage**

Mexico City,
S.F. Bay Area,
Provo
Salt Lake City

- **50-250 miles from epicenter**

- **Severe Damage!**



Aftershock in the Bay Area, 1989

Sand Blows from 1934
M=6.7 Hansel Valley EQ

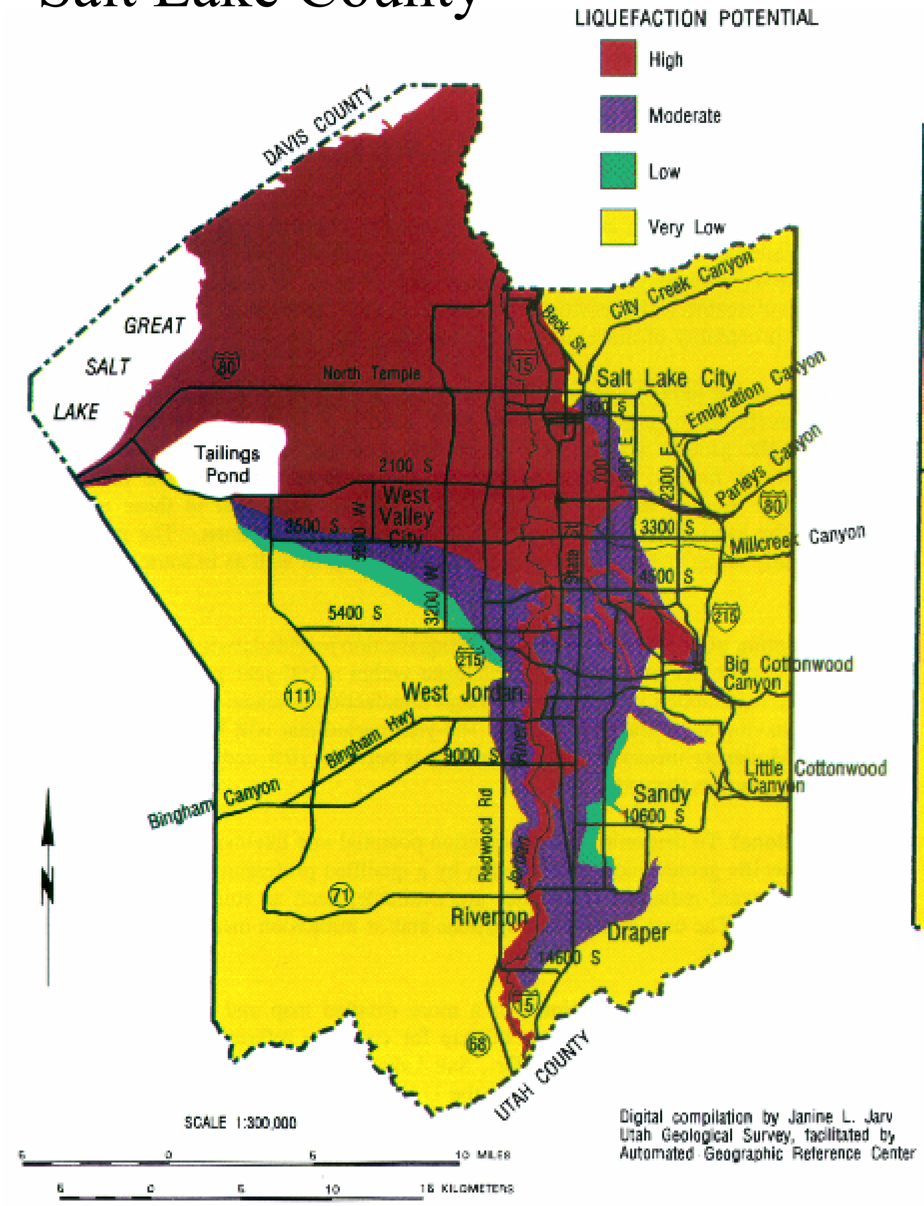
Photos courtesy of Special Collections Department, University of Utah Libraries

Liquefaction is when saturated sandy soil turns to quick-sand during moderate to strong ground motion.

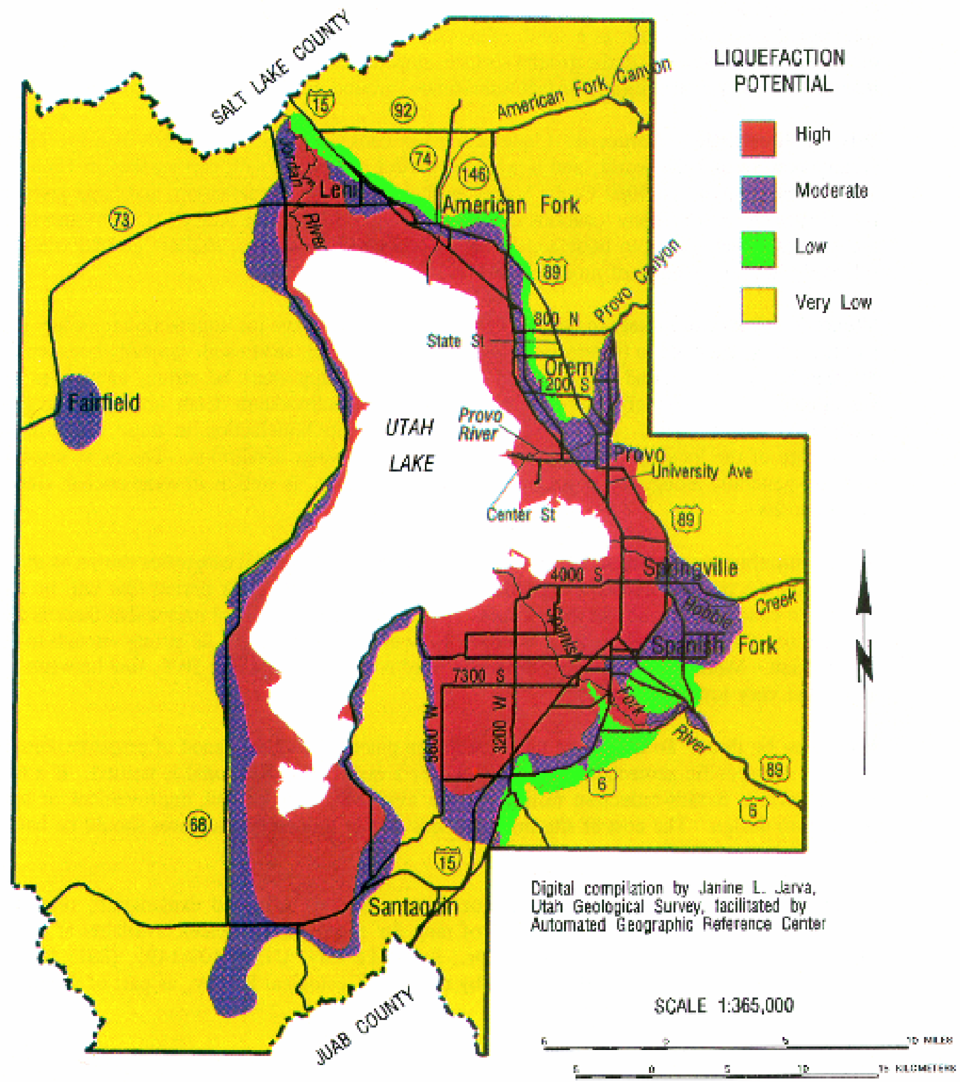
- heavy things sink (buildings, people)
- light things rise (gas lines)

Liquefaction-Potential Maps

Salt Lake County



Utah County



How Much Damage?

This brick garage collapsed onto a car in Richmond.
Photo courtesy of Ogden Standard Examiner, Ogden, Utah

Bottom two photos show inside buildings where plaster cracked and fell, as did bricks and furnishings.

Left: A chimney fell through the roof and landed on this man's bed just as he was getting up. Notice the plaster and wood damage.

Right: Brick and plaster fell on this bed. The woman, who was in bed at the time, fortunately escaped with only a bruise.

Photos courtesy of Ariel D. Benson, Richmond, Utah

Cache Valley Earthquake, 1962

- M = 5.7 (one Hiroshima Bomb)
- Two major landslides
- 75% of buildings in Richmond were damaged
- Gas lines ruptured
- Over 1 million in damage (1962 dollars)

Earthquakes do not kill, falling objects do.

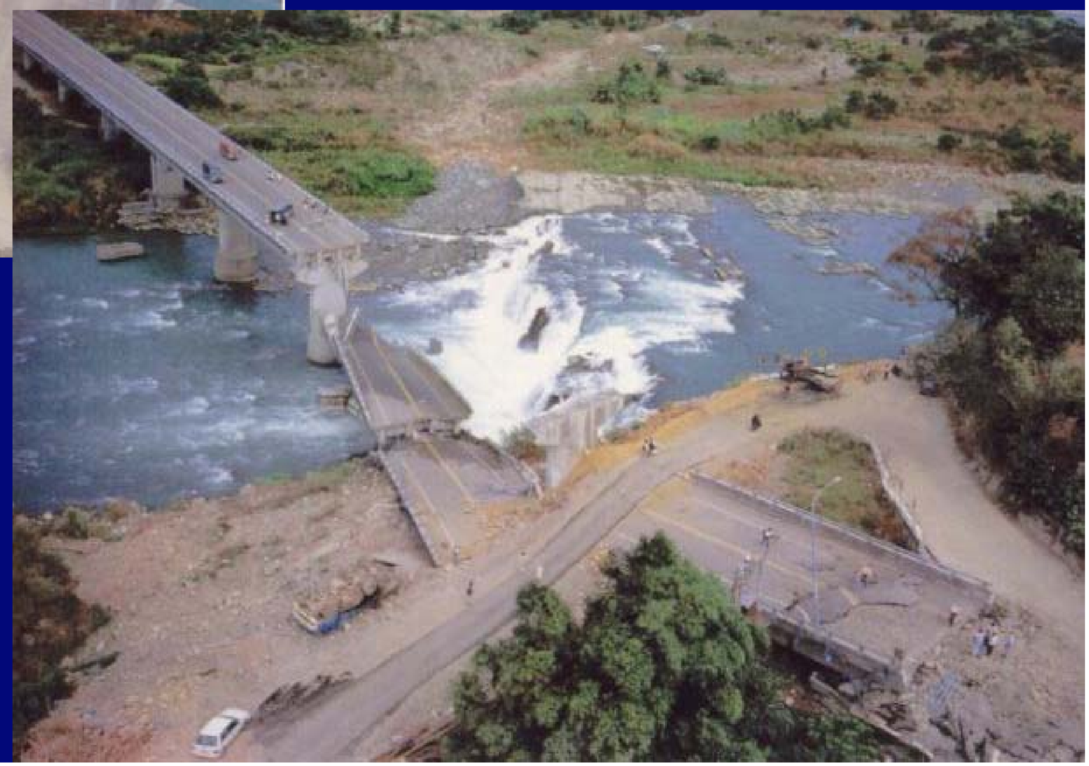
Plaster was knocked from the ceiling onto the seats in the Benson Stake Tabernacle in Richmond. Structural damage from the earthquake caused this building to be torn down.

Photo courtesy of Ariel D. Benson, Richmond, Utah

M = 7.0 is 13 times more motion and 400 times more energy than M =5.7

(1 vs. 50 Hiroshima Bombs)

What about Critical Facilities?



Chi Chi Earthquake, Taiwan (1999)

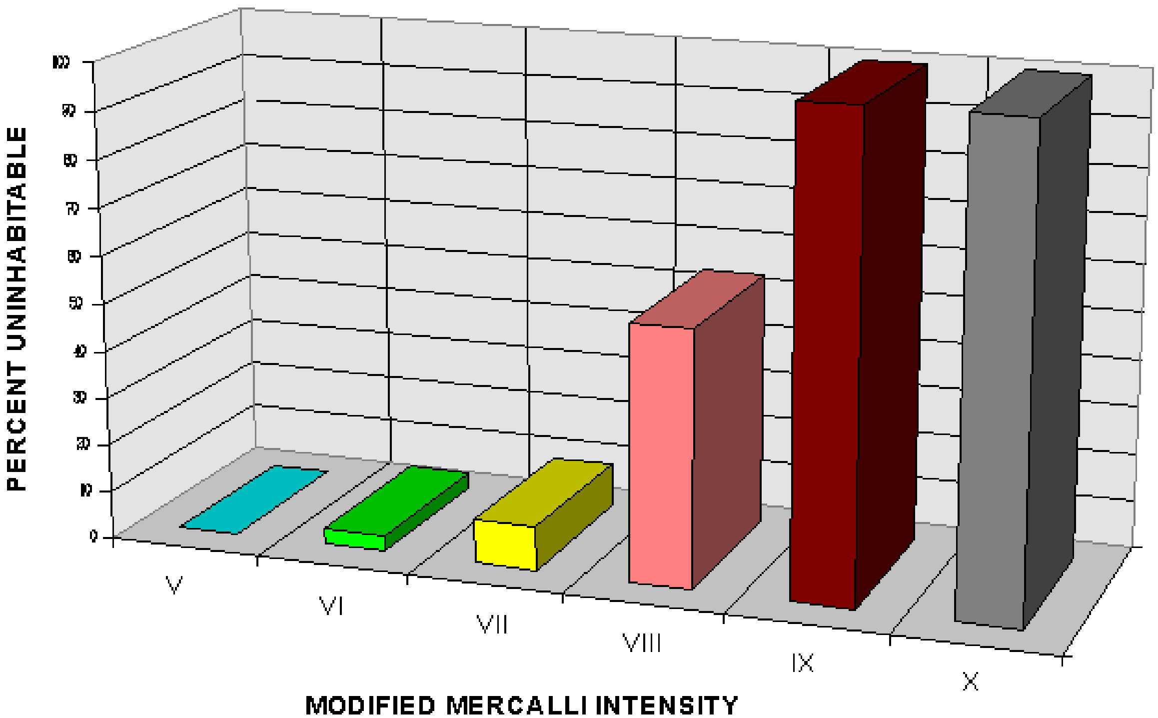
Protecting Ourselves: Disaster Prevention

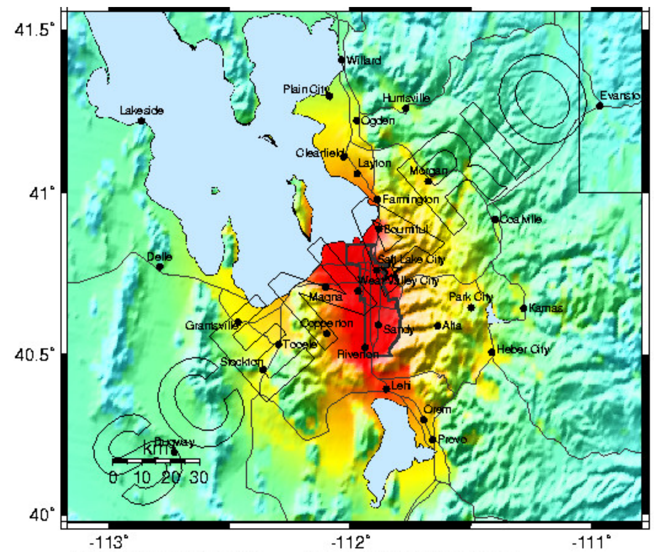
Construction and retrofitting

- Building Materials (unreinforced masonry)
- Construction practices (before or after 80’s)
- Buildings attached to foundation and roof

The 3 Pigs had it all wrong!

UNREINFORCED MASONRY
PERCENT UNINHABITABLE BY MMI INTENSITY LEVEL

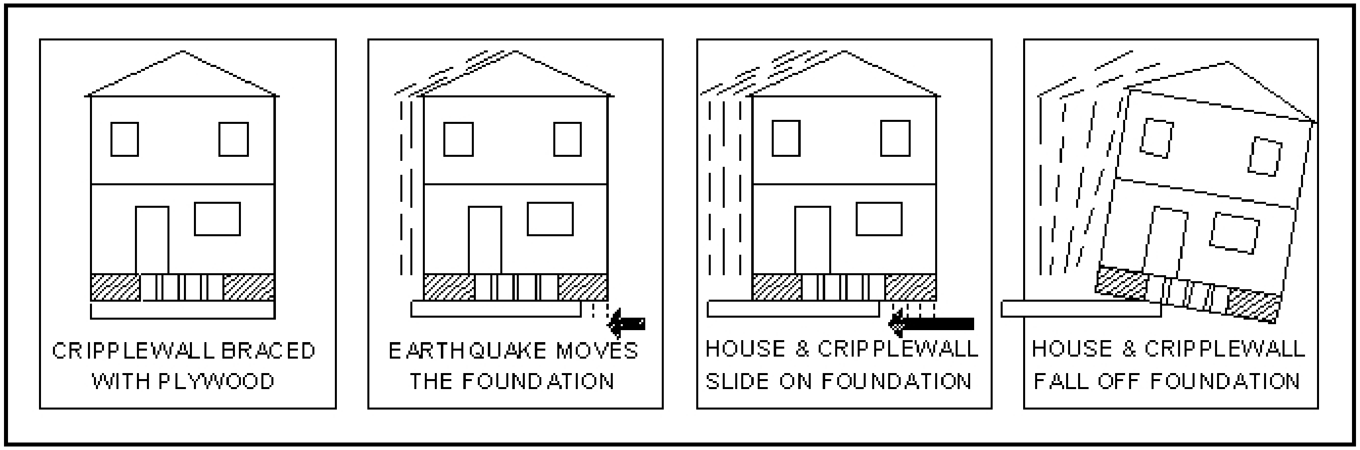




PLANNING SCENARIO ONLY – Processed: Thu Sep 23, 2004 12:14:31 PM MDT

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+

"The only thing we have to fear, is ***shear*** itself"



Protecting Ourselves: Disaster Prevention

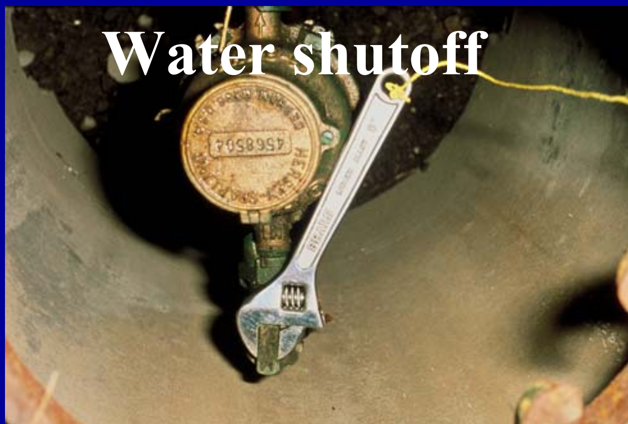
Securing items in buildings

- Water Heater, appliances, book shelves, canned food
- Gas and water lines

Fire


RUINS OF SAN FRANCISCO
HILL IN FOREGROUND
LAWRENCE CAPTIVE
1500 FEET ELEVATION

Are earthquakes the real threat, or is ignorance and apathy?



Check List of 'Least Regrets'

- **Faults**
  - ✓ Identify and characterize fault zones (geologic mapping, instrumentation, fault history studies, geophysical methods).
  - ✓ Determine earthquake potential and recurrence intervals (age analysis of geological and trench data, geodetic studies).
  - ☐ Adopt guidelines, land-use policies and regulations for development in high risk areas.

- **Ground shaking**
  - ✓ Identify geographic areas expected to experience strong ground shaking (geologic mapping, geophysical and geotechnical studies)
  - ✓ Construct probabilistic maps of the ground shaking hazard
  - ☐ Adopt guidelines, regulations, and inspection procedures for development in areas expected to experience strong ground shaking.

Modified from Global Blueprints for Change, 2001

Check List of 'Least Regrets'

- **Ground failure**
  - ✓ Identify sites susceptible to ground failure (i. e., liquefaction, lateral spreads, and landslides)
  - ☐ Review development plans in most susceptible areas.
  - ☐ Adopt zoning ordinances and regulations to manage development in the most susceptible areas.

- **New construction**
  - ☐ Review all new construction of public buildings and infrastructure (uses, characteristics of site, and construction materials).
  - ☐ Determine ground shaking and ground failure hazards the structure will be exposed to during its useful life.
  - ☐ Adopt regulations that set seismic safety policies, acceptable risk, and professional practices for new development.

Check List of 'Least Regrets'

- **Existing construction** (collapse-hazard buildings and weak infrastructure)
  - ☐ Locate, identify, and assess the vulnerability of high-occupancy and other buildings with respect to their collapse hazard.
  - ☐ Inform building owner of findings and adopt standards for repair and strengthening.
  - ☐ Implement repair and strengthening program.

- **Essential and critical facilities** (e.g., government buildings, schools, hospitals, water, gas,power
  - ☐ Locate all essential and critical facilities and assess their vulnerability.
  - ☐ Adopt, enact and enforce performance standards.
  - ☐ Strengthen, relocate, or replace the facility when the standard can not be met.
  - ☐ Plan redundancy.

What Can We Do Now to Protect Ourselves?

- Educate Family, Employees and Neighbors about earthquake hazard (www.utahearthquake.org)

- Protect yourself and others
  1. Identify potential hazards in living and work spaces and fix them (retrofit buildings and secure objects).
  2. **Schools! Businesses!**
  3. Create and practice a disaster plan.
  4. Assemble disaster supplies kit.
  5. During quake drop, cover and hold on.
  6. When safe, follow emergency plan.

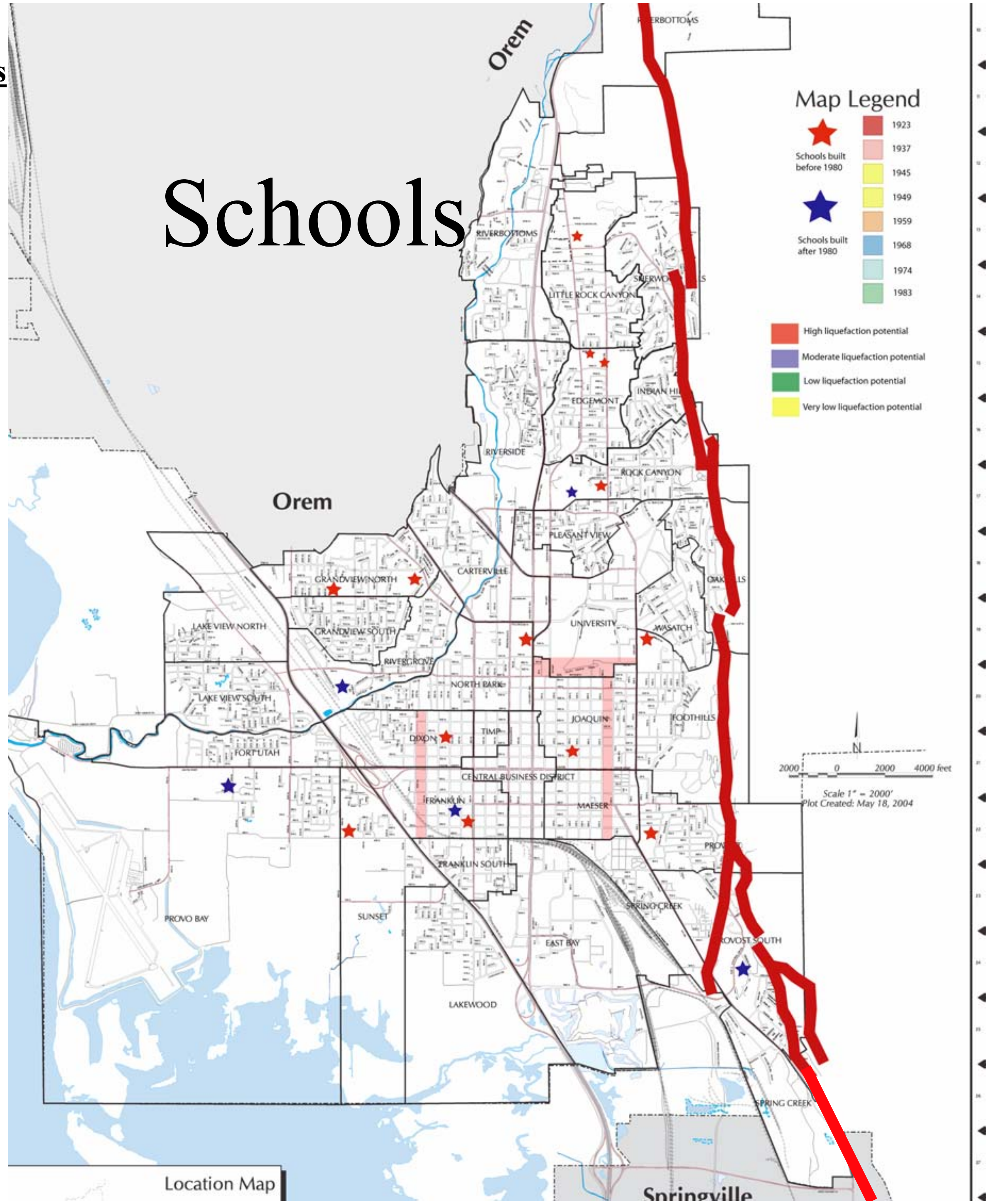
We Live By Geologic Consent!

Questions?

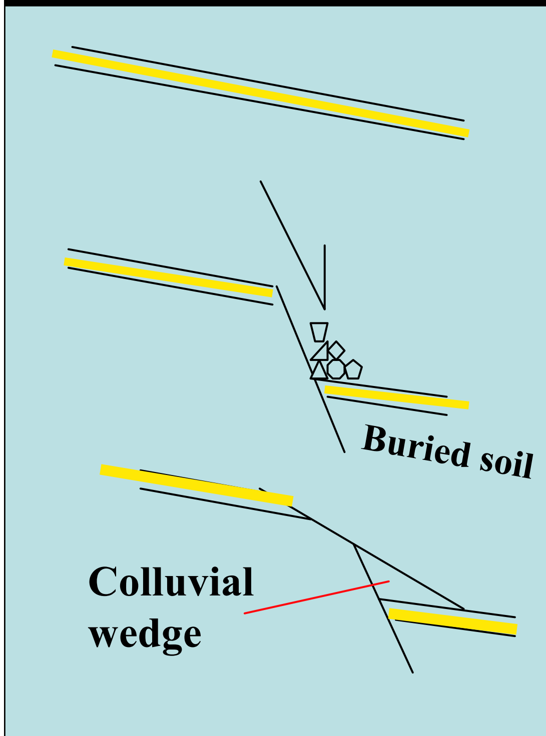
Schools

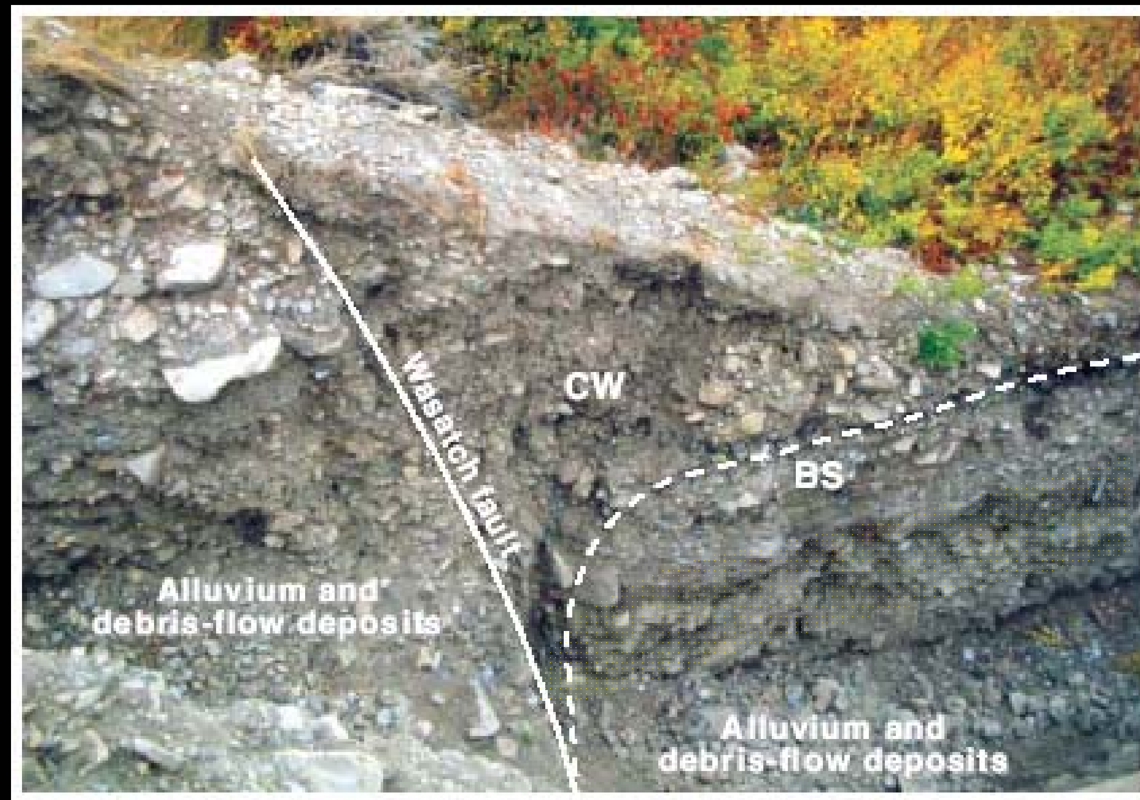
Building	Date	Students
Admin	1965	?
Elementary Schools		
Amnelia	1999	651
Canyon Cr.	1982	554
Edgemont	1955	488
Farrer	1931	427
Franklin	1901 (94)	532
Grandview	1949	532
Provost	1949	441
Rock Cany	1964	579
Spring Cr.	2002	559
Sunset V.	1959	637
Timp.	1938	539
Wasatch	1949	587
Westridge	1979	800
		6116
Middle Schools		
Centinneal	1996	977
Dixon	1931	934
High Schools		
Provo	1956	1940
Timpview	1974	1706
		3646

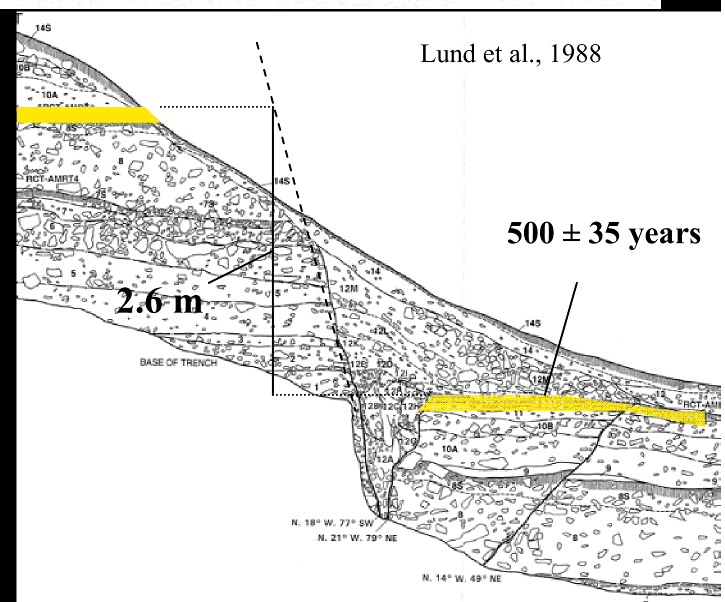
Students in Unreinforced Schools = 10,796

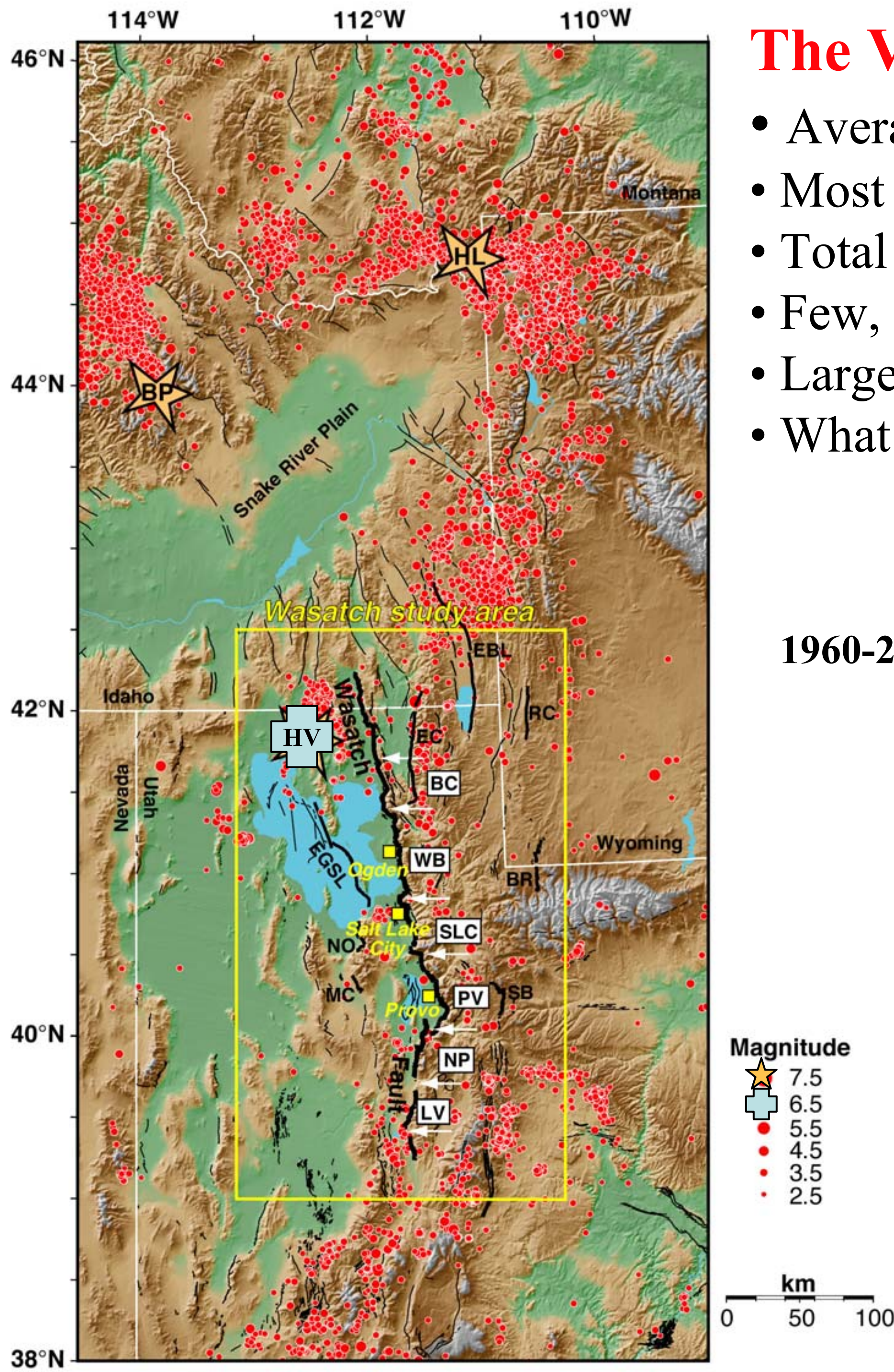


What does an Ancient Earthquake Look Like?





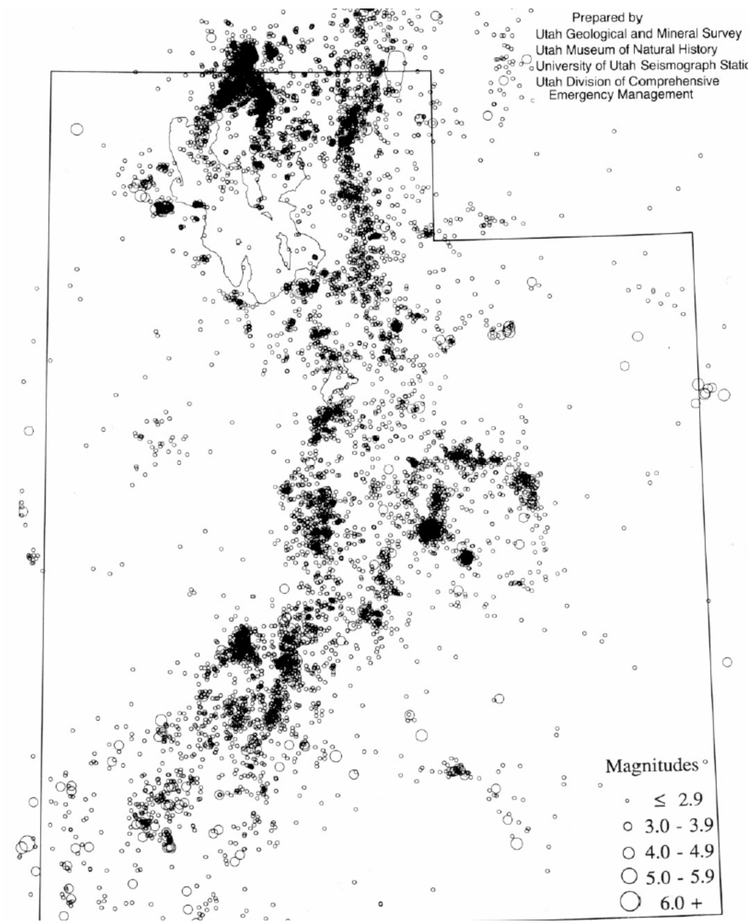




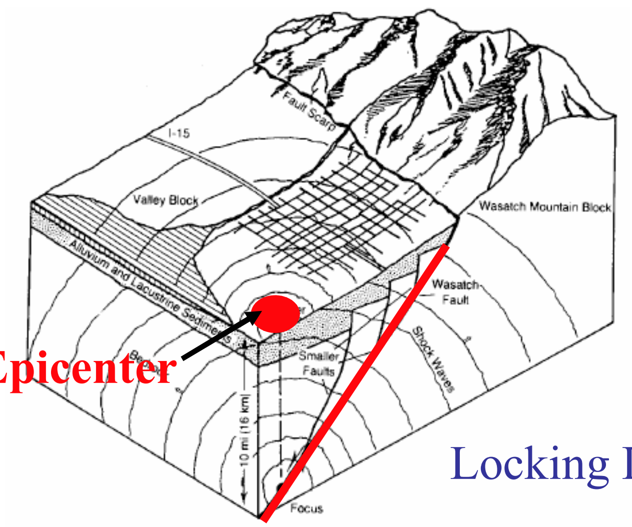
The Voice of Earthquakes!

- Average 75 earthquakes per month
- Most events are weak parts of the fault slipping
- Total slip = 0.02 mm/yr.
- Few, if any, mid-range events (M=5.0 - 6.5)
- Largest historic event in Utah M = 6.7 (1934)
- What about large events, like Borah Peak?

1960-2000



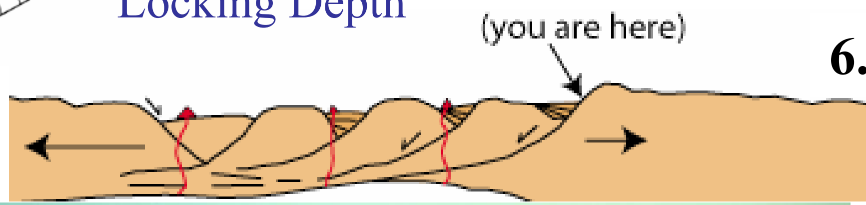
What is the Wasatch Fault?

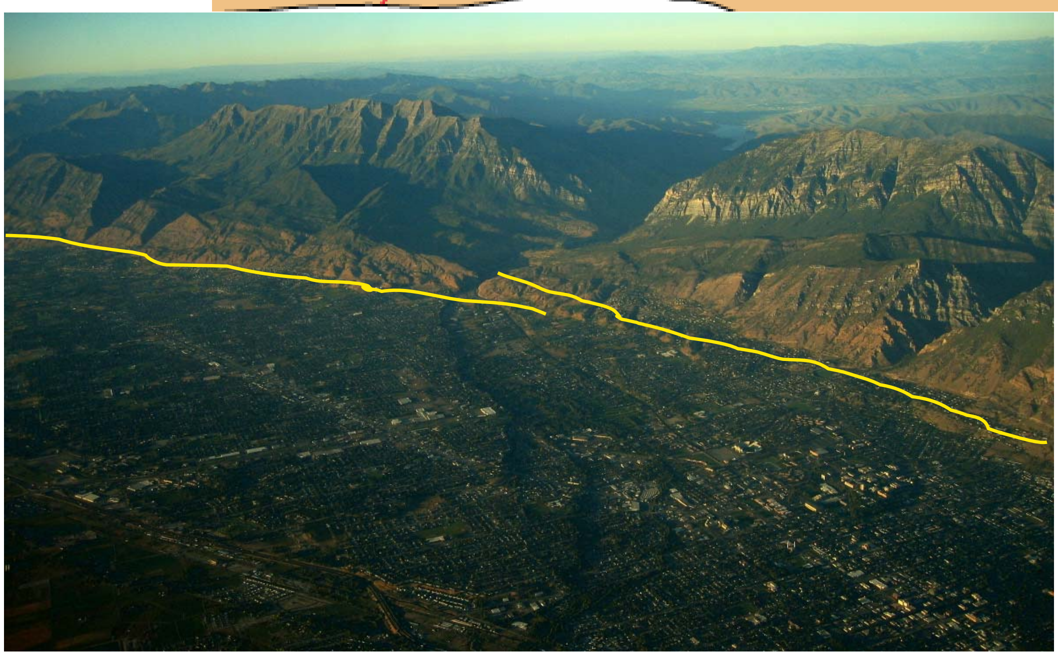


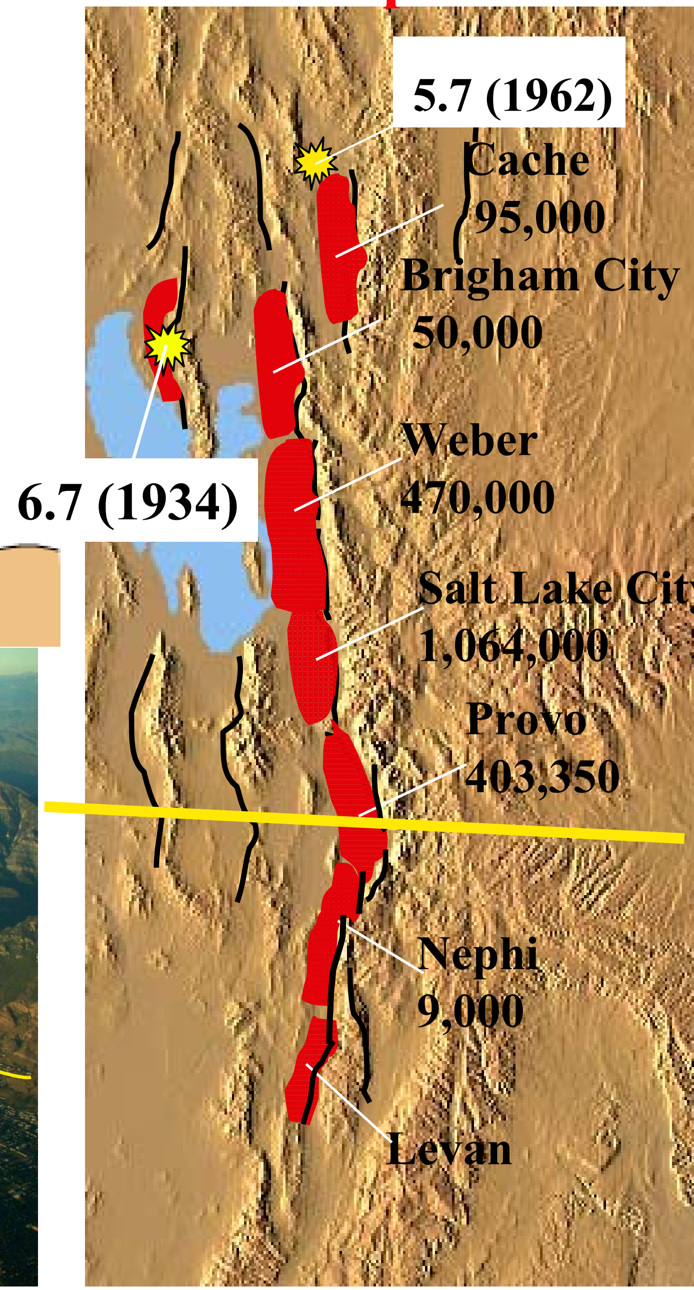
2.1 million people live on the *Wasatch Fault*

Fault Segments and Population

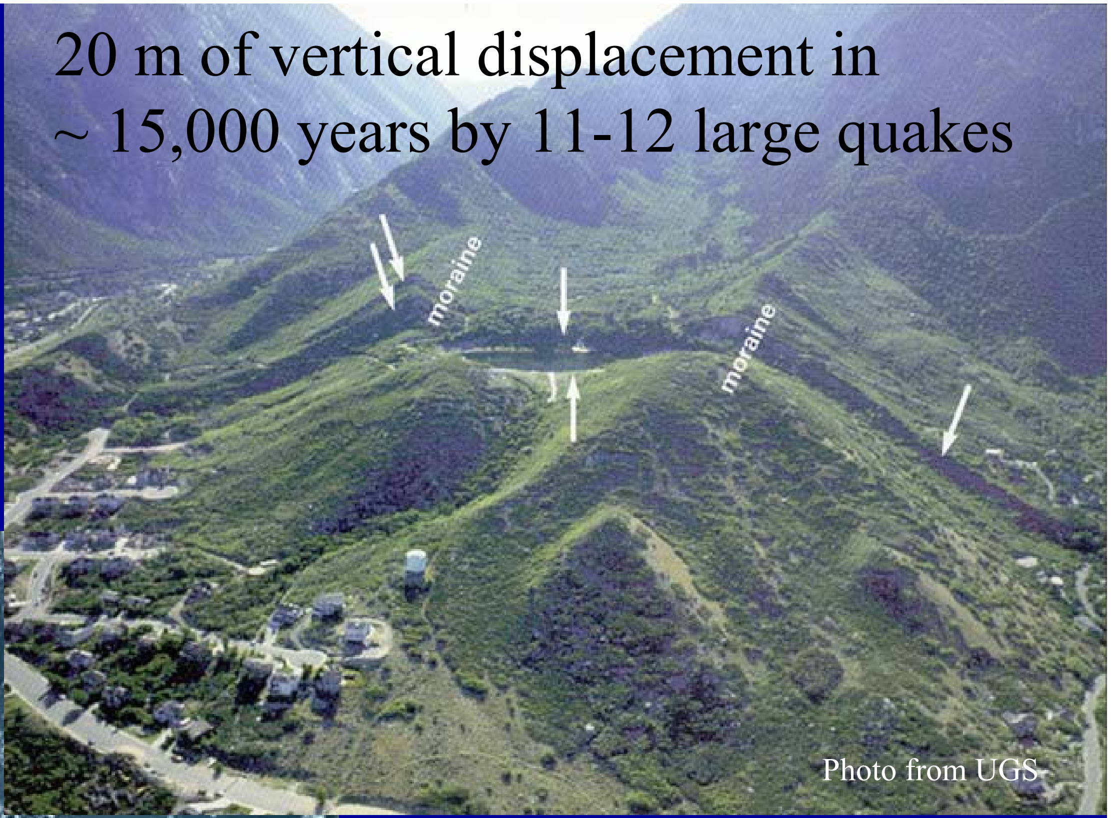
Locking Depth

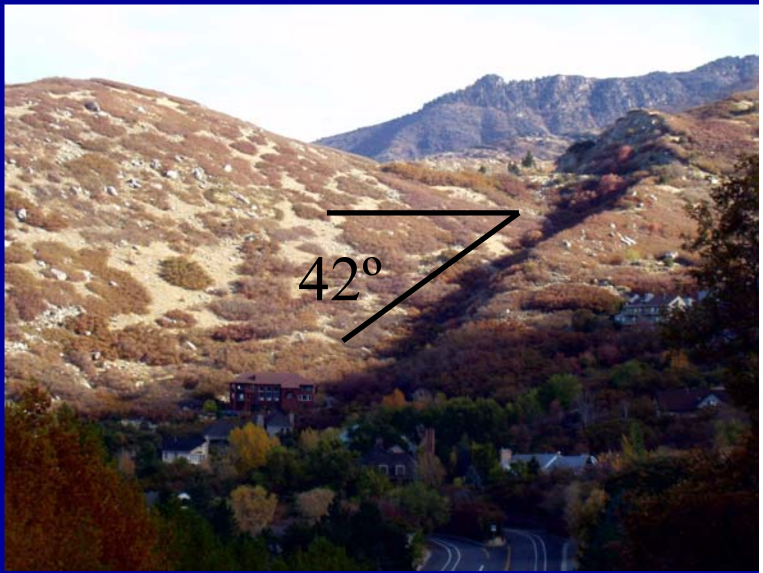




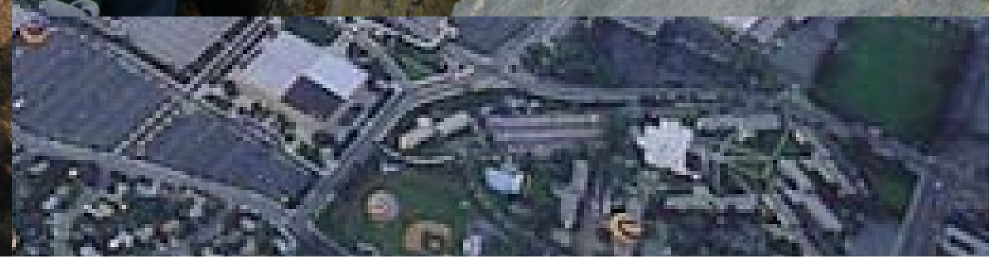


Where is the Wasatch Fault?

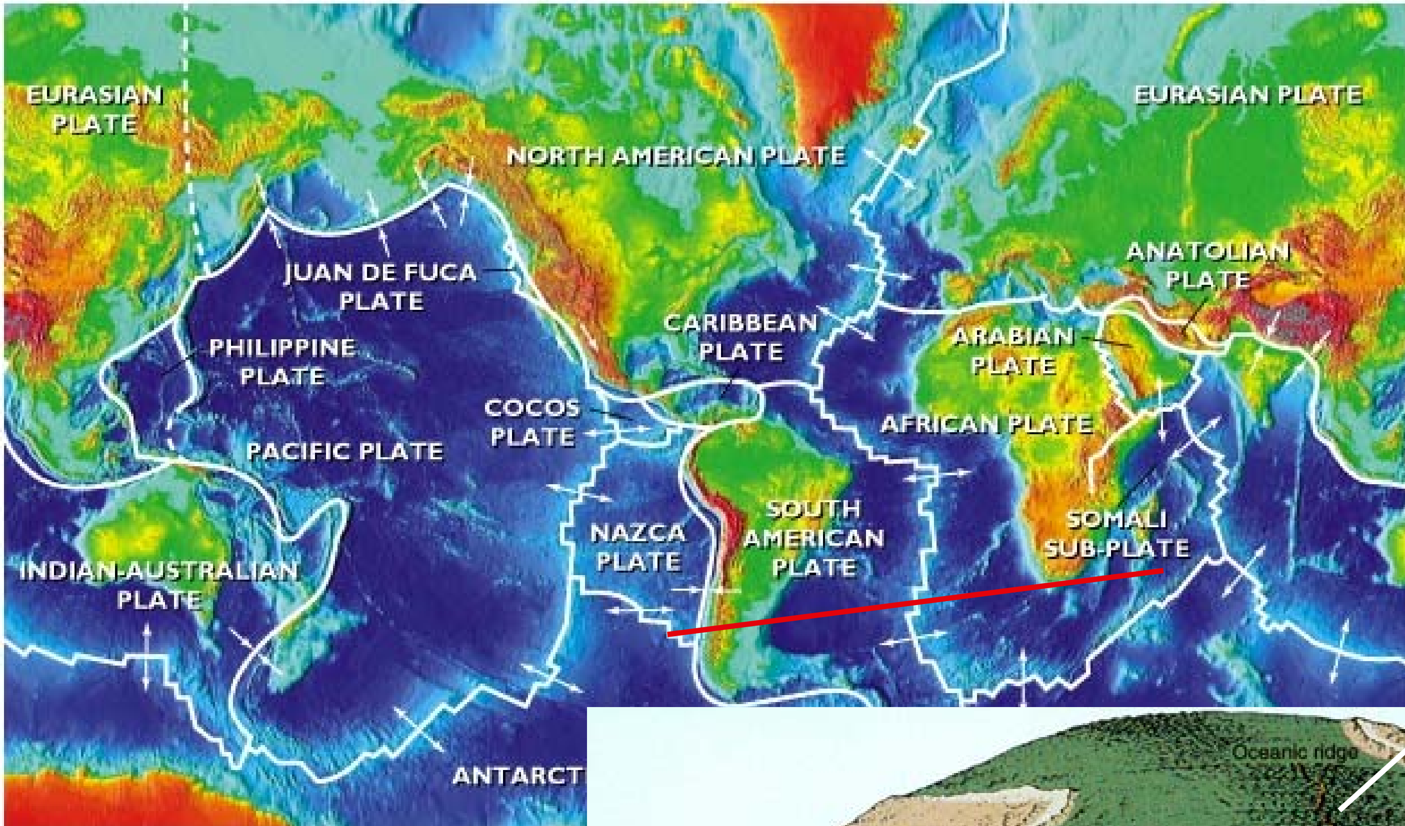


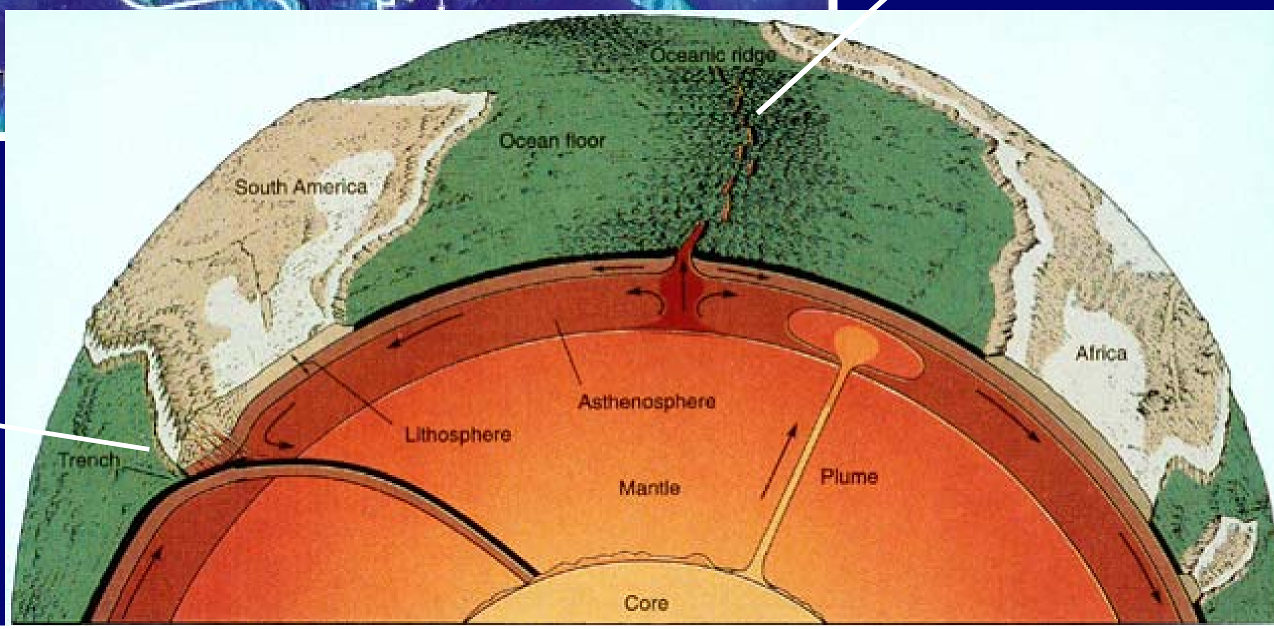




How and Why Earthquakes?

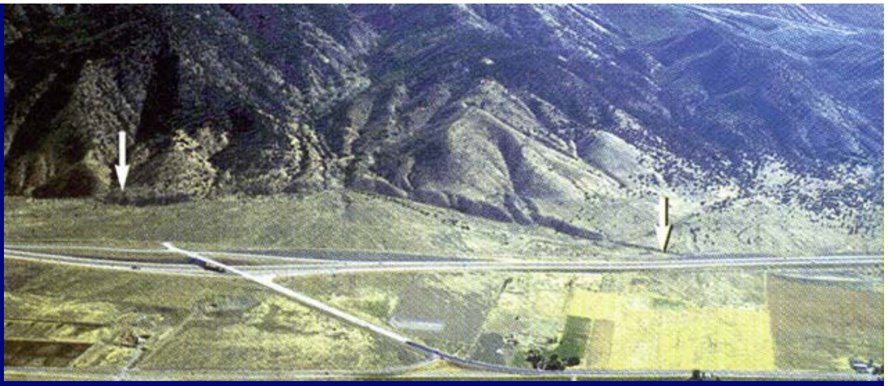




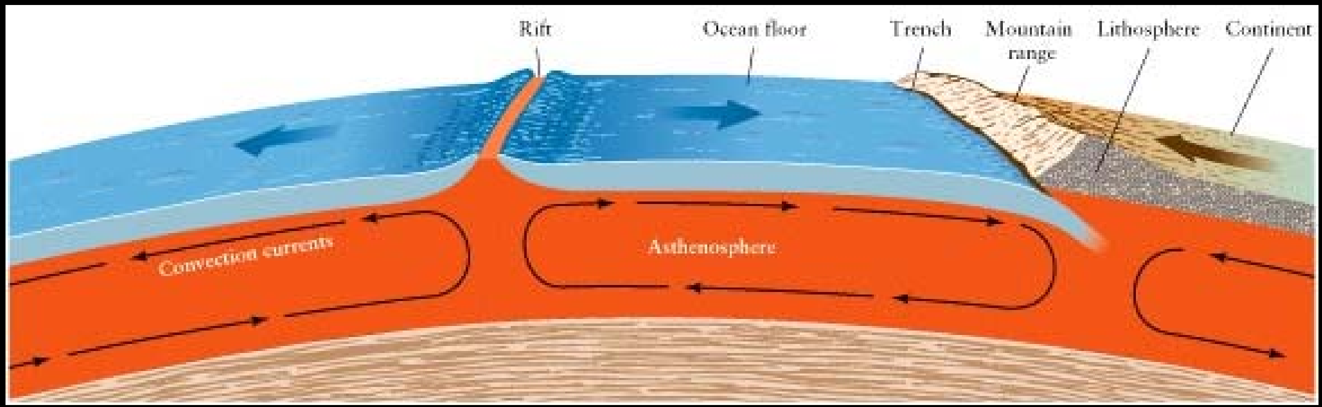
Breaking Continents: Plate Divergence

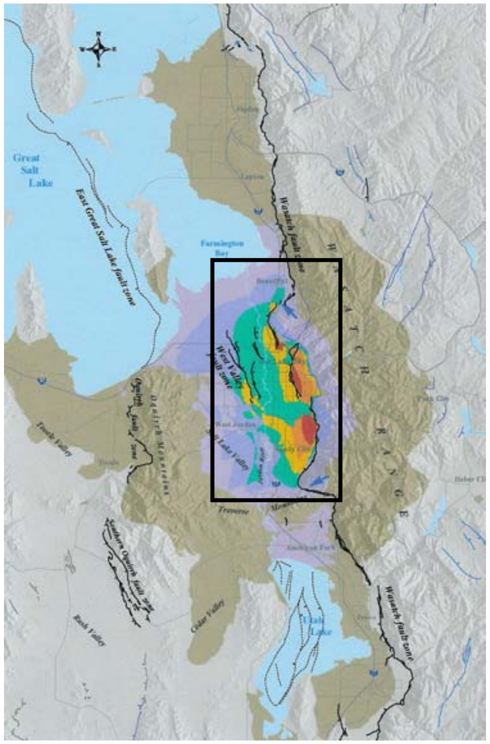
Making Continents: Plate Convergence

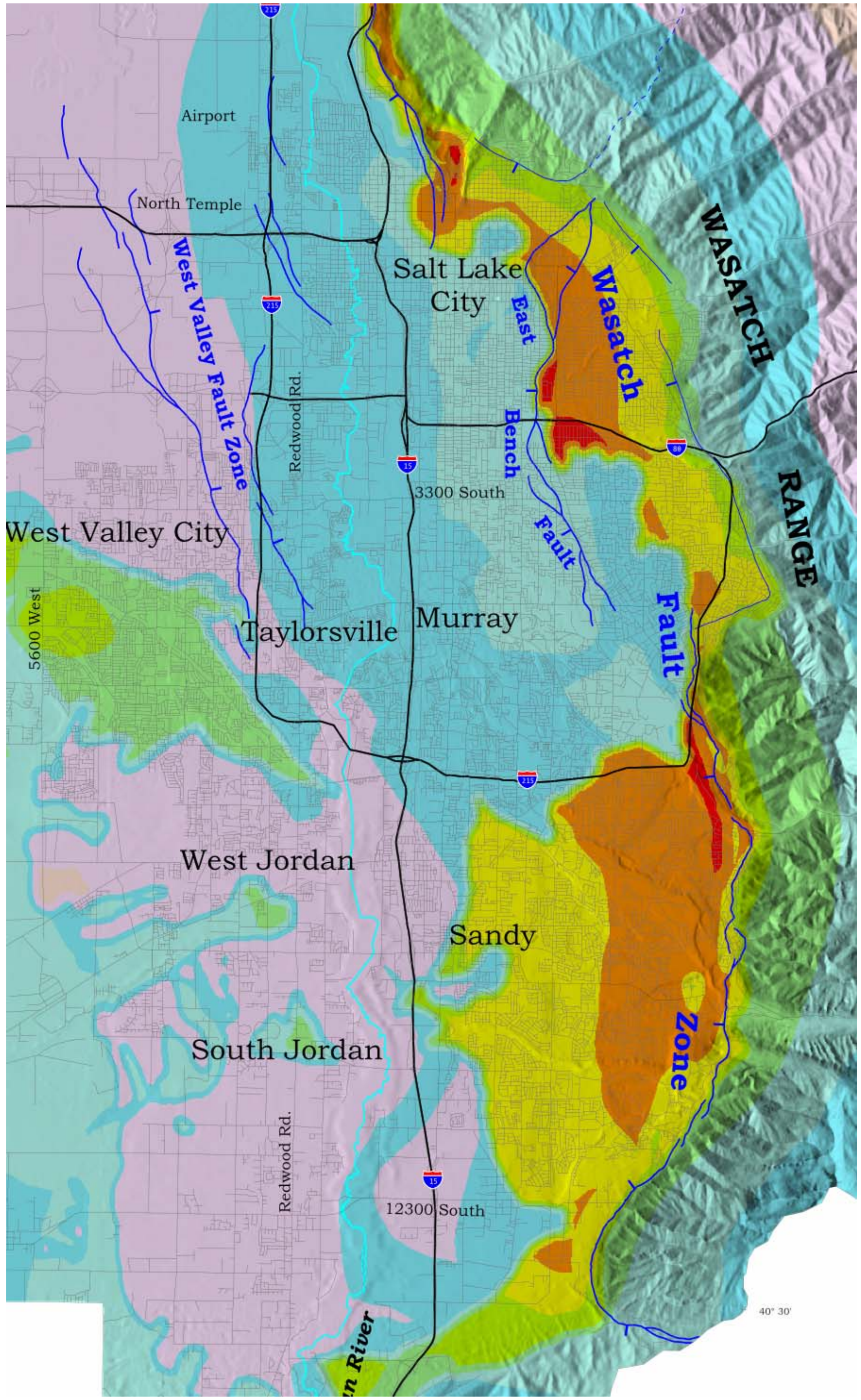
Southern Wasatch Fault



What Causes Earthquakes?

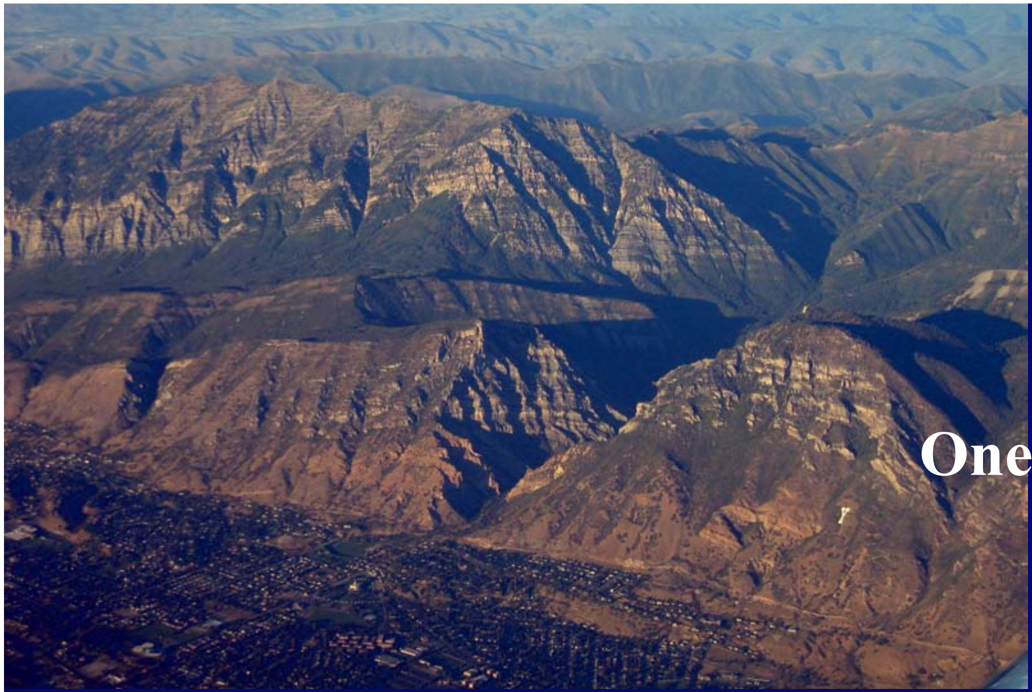






Predicted Peak Horizontal Accelerations (g) for $M_w = 7.0$ Earthquake

Acceleration (g)	Intensity
0.1 - 0.2	VI
0.2 - 0.3	VI / VII
0.3 - 0.4	VII / VIII
0.4 - 0.5	VIII
0.5 - 0.6	VIII
0.6 - 0.7	VIII / IX
0.7 - 0.8	IX
0.8 - 0.9	IX
0.9 - 1.0	IX
1.0 - 1.1	IX



How Did the Wasatch Front Form?

One Large Earthquake at a Time!

QuickTime™ and a
Sorenson Video decompressor
are needed to see this picture.

Why Should We Care and Act Now?

1994 Northridge Earthquake

- Economic loss of $49 billion
- 20,000 plus people homeless
- Damaged up to 1,000 buildings
- Major Transportation Infrastructure Destruction
- Business Damage & Disruptions
- Aggregate Business Losses nearly $6 billion
- Business Physical Damage: 57%
- Business Relocation: 5%

Kobe

- $200 billion, 200,000 dwellings and buildings, 350,000 homeless

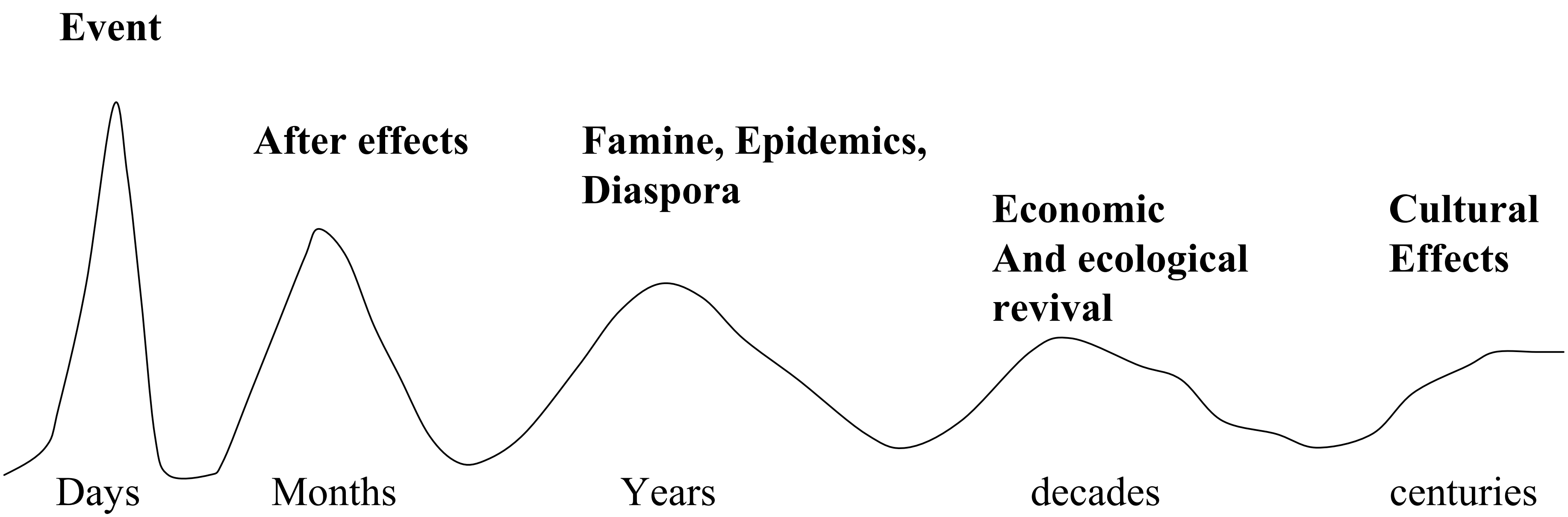
US Natural Disaster Costs: At present, the average economic toll from natural hazards in the United States reaches $52 billion per year---$1 billion per week---about one-third of the worldwide toll. The average annual death toll is about 150,000 worldwide but is only about 200 in the United States.

- Overall about 4,000 buildings were severely damaged or destroyed and another 8,500were moderately damaged. Seven major freeway bridges in the area collapsed, and 170 weredamaged, disrupting traffic in the Ventura-Los Angeles region for weeks following the **earthquake**.Communication, water and power distribution systems were also affected. The **earthquake**highlighted the vulnerability of apartment complexes built over parking garages (buildings with a課ㅈsoft課□ story). Many of these buildings sustained significant damage due to failure of columns at theparking level. Several precast tilt-up structures were also badly damaged due to the collapse of tilt-up walls. Nine parking structures collapsed, and nine hospitals had to be closed immediately afterthe **earthquake**. While much less visible than the collapses, many large steel frame buildings sufferedsignificant cracking in their principal beam connections. Although limited in their extent, severalfires broke out, including one that burned seventeen homes in a mobile home p
- Although the emphasis on saving lives did not necessarily correlate to lower levels of economic loss, the earthquake showed that investments in building codes and engineering practice did yield good returns. For example, the lack of collapse and heavy damage to unreinforced masonry buildings, which were seismically strengthened under a Los Angeles ordinance passed in the early 1980s (Division 88) was credited for saving many lives as well as protecting several small businesses that typically operate in these buildings. Similarly, the post-San Fernando earthquake initiative toward making hospitals and other critical facilities more resilient to earthquake shaking resulted in improved performance of these types of structures compared to the damages seen during the 1971 earthquake. Further, the earthquake demonstrated that public awareness and preparedness efforts were efficient in improving the response of the population and facilitating the emergency procedures. These conditions limited the losses and facilitated the regionㅗs recovery.
- Losses equated to 28 times the aggregate earthquake premium collected in 1993, and far exceeded the historical earthquake premiums to date. A few insurers teetered on the verge of insolvency. For the majority who remained viable despite the unprecedented scale of losses, i

“Building a culture of prevention is not easy. While the costs of prevention have to be paid in the present, its benefits lie in a distant future. Moreover, the benefits are not tangible; they are the disasters that did not happen.”

Koffie Annan, Secretary General of United Nations (1999)

The 'Vibrating String' of Geologic Hazards



Direct and indirect

Eruption	VEI	Deaths	Destruct	Climate	Culture
Yellowstone (2.5 Ma)	8	Extinction of early hominds		Global Volcanic Winter, acid rain	Massive Extinctions
Toba (70-80 Ka)	8	Near human extinction	2800 km3 30 cm @ 2,500 km	Global Volcanic Winter, acid rain	Near extinction of man and creation of an "evolutionary bottleneck"
Santorini (~1650 BC)	7	1000's	60 m of Ash, tsunami	cooling	Fall of Minoan Civ. and rise of Mycenaean Greece. Mythologies, Plagues of Egypt, Atlantis
Book of Mormon? (34 AD)	5-6	16 cities	Ashflow tsumani Lahar?	?	Near extinction of B of M peoples. 400 yrs. of righteousness.
Tambora (1815)	7	90,000	50 km3 of Ash, 4 days darkness	3-4 degrees cooling for years	After 3 yrs. of crop failure in US, thousands migrated westward, including J. S., Sr. Global cholera epidemic and food riots of Europe.