

Forensic Engineering Geology of Landslides

Dr. Scott Burns, Professor Emeritus
Department of Geology
Portland State University
2011-12 Richard Jahns Lecturer
Past President, AEG and IAEG

Outline of Talk

- **Introduction – Why give the talk**
- **Oso Landslide – the Game Changer**
- **Field Signs/Factors**
- **Process**
- **Reactivation of Ancient Landslides**
- **Control of Water**
- **Earthquake Triggered Landslides**
- **Conclusions**

Forensic Engineering: Environmental Case Histories for Civil Engineers and Geologists

- 1992
- Gerard Shuirman and James Slosson
- This book inspired me into connection of evaluating landslides and the importance of case histories

**Each Year: 25-50 deaths in
North America
And \$3.5 billion damage**





Oso Landslide, Washington
March 22, 2014: America's Deadliest Landslide
2000's

B e f o r e s l i d e





Downed power lines in debris on March 23, 2014

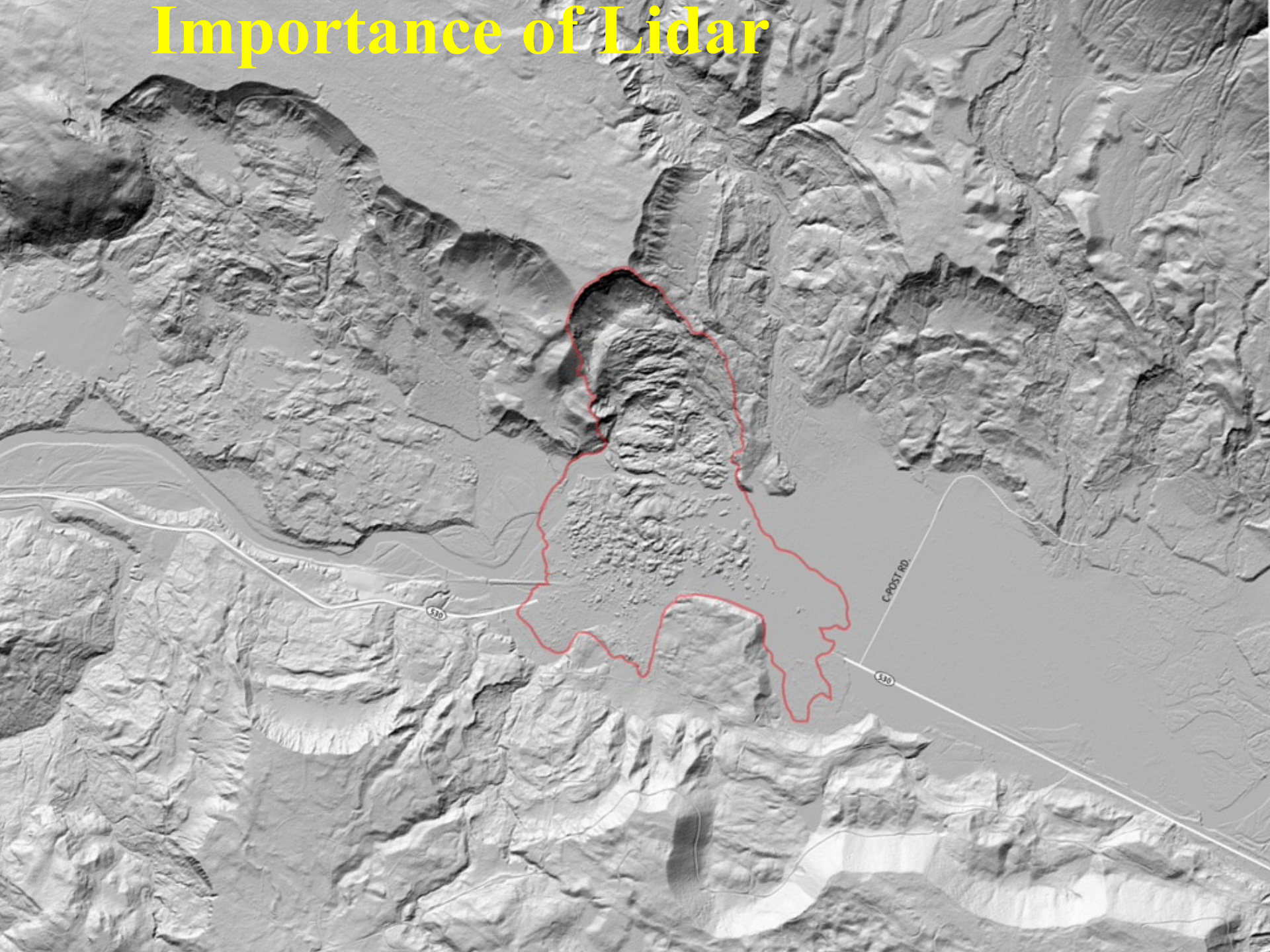
Details of the Oso Landslide

- 43 Dead
- 45 Homes destroyed (25 full time residents)
- Losses: \$7 million houses, \$3 million contents, \$150 million in rescue and removal of debris after the event
- 3rd Most Deadly landslide in US history
- Poster Child for Landslides in Pacific Northwest

Geology of the Landslide

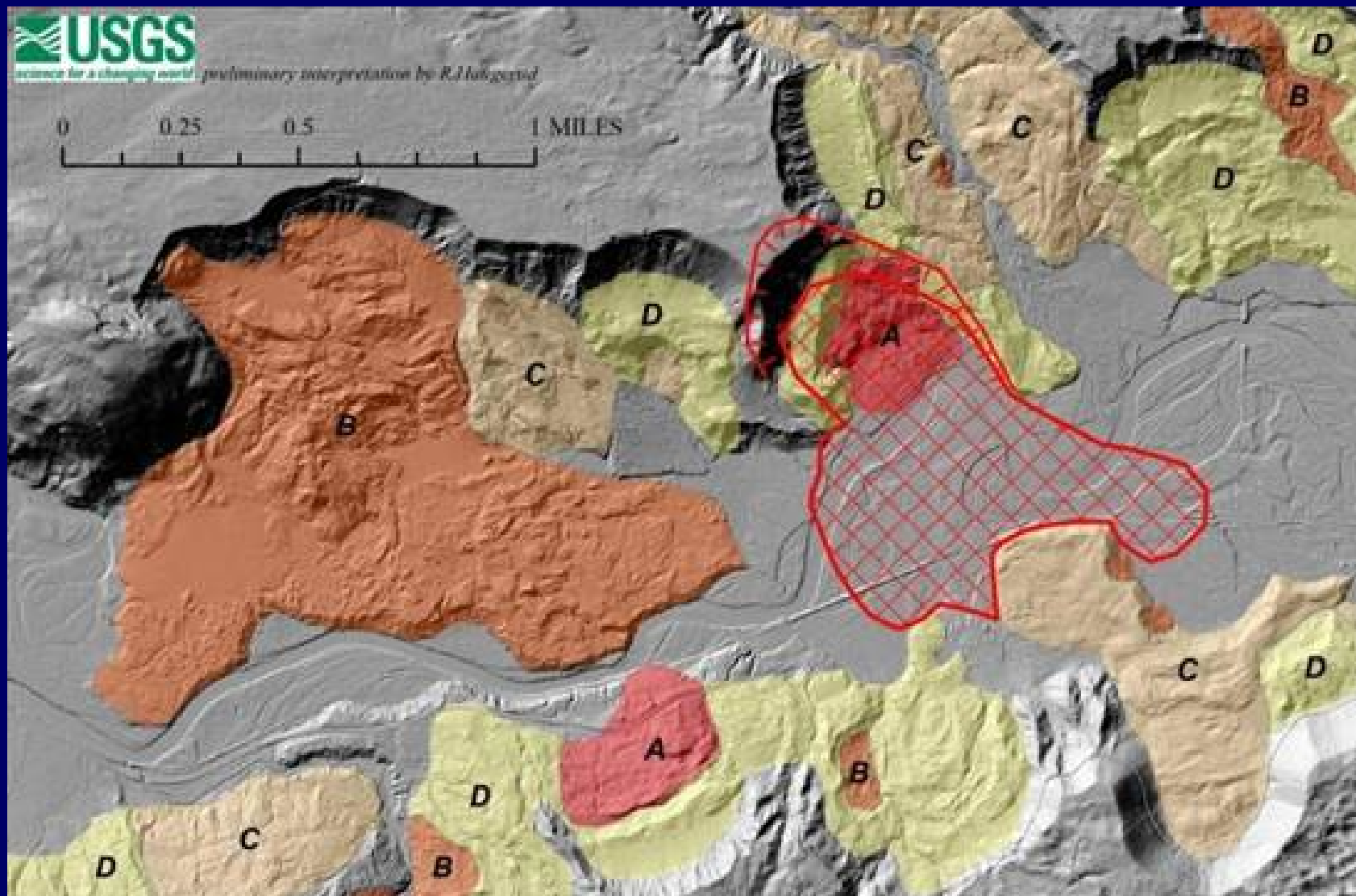
- 10 million cubic meters of debris
- Debris Avalanche then Debris Flow; 60 sec
- Previous slides: 1951, 1967, 1988, 2006
- Record Rainfall in March of that year
- River undercutting the slope
- Weak soils and Steep slope
- 15 large landslides in valley in last 6000 years

Importance of Lidar





preliminary interpretation by R. H. Haggstad



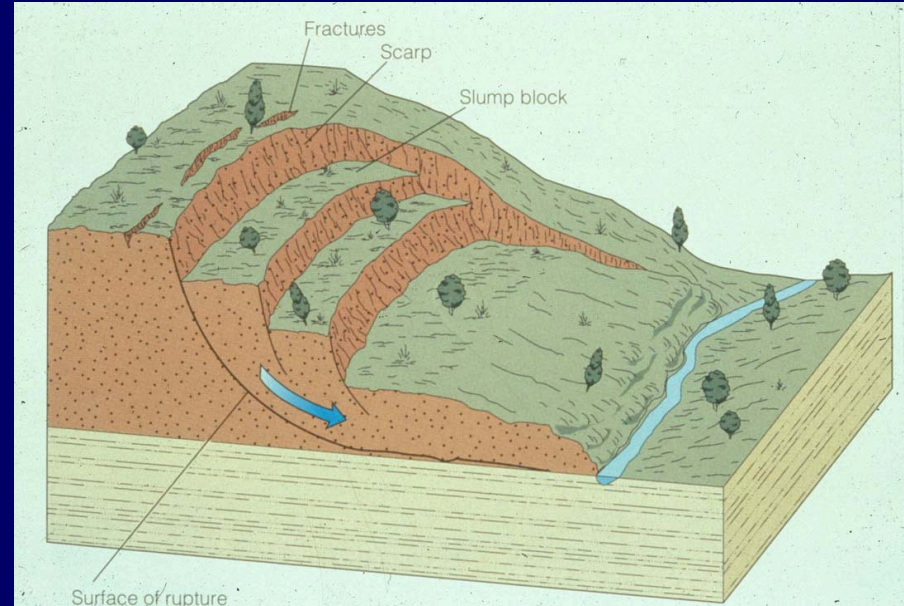
Is it an Ancient Landslide?

- **Hummocky Topography/Sag Ponds**
- **Scarp**
- **Unsorted parent material**
- **Different Vegetation**
- **Note – if it has moved once, it can move again unless you control the driving forces**

Bonneville Landslide Complex



Field Signs



Field Signs



Field Signs are Important



FACTORS

- Parent Material (cohesion, clay%)
- Slope Angle
- Water in parent material
- Vegetation
- Ancient Landslide? Reactivation is a major theme – must map past landslides
- Triggers: Water or Earthquakes

Using Field Reconnaissance to develop mitigation procedures

- **First thing – safety program**
- **Site Evaluation – geology, slope angle, etc**
- **Field Developed Cross Section; Rainfall**
- **Parent Material, Slope angle, Bedding, Vegetation, Failure planes, volumes**
- **Borings and Geophysical cross sections**
- **Put info into models for FS; is it > 1 ?**
- **Working Hypotheses; Is it Reactivation?**
- **Mitigation ideas; range finders and drone**

Stabilization/Prevention

- **Reduce the Driving Forces**
- **Increase the Resisting Forces**
- **Reduce the Slope Angle**
- **Drainage**
- **Reinforcing Walls and Buttresses**
- **Rockfall: bolts, shotcrete, screens, use the Oregon Rockfall Rating System**

Determine the Process!

- Falls
- Slump
- Translational Slide (failure plane)
- Earthflow (no failure plane)
- Debris flow or Mudflow
- Debris Avalanche

Rockfall Problems Around the Bend!





Zermatt Valley



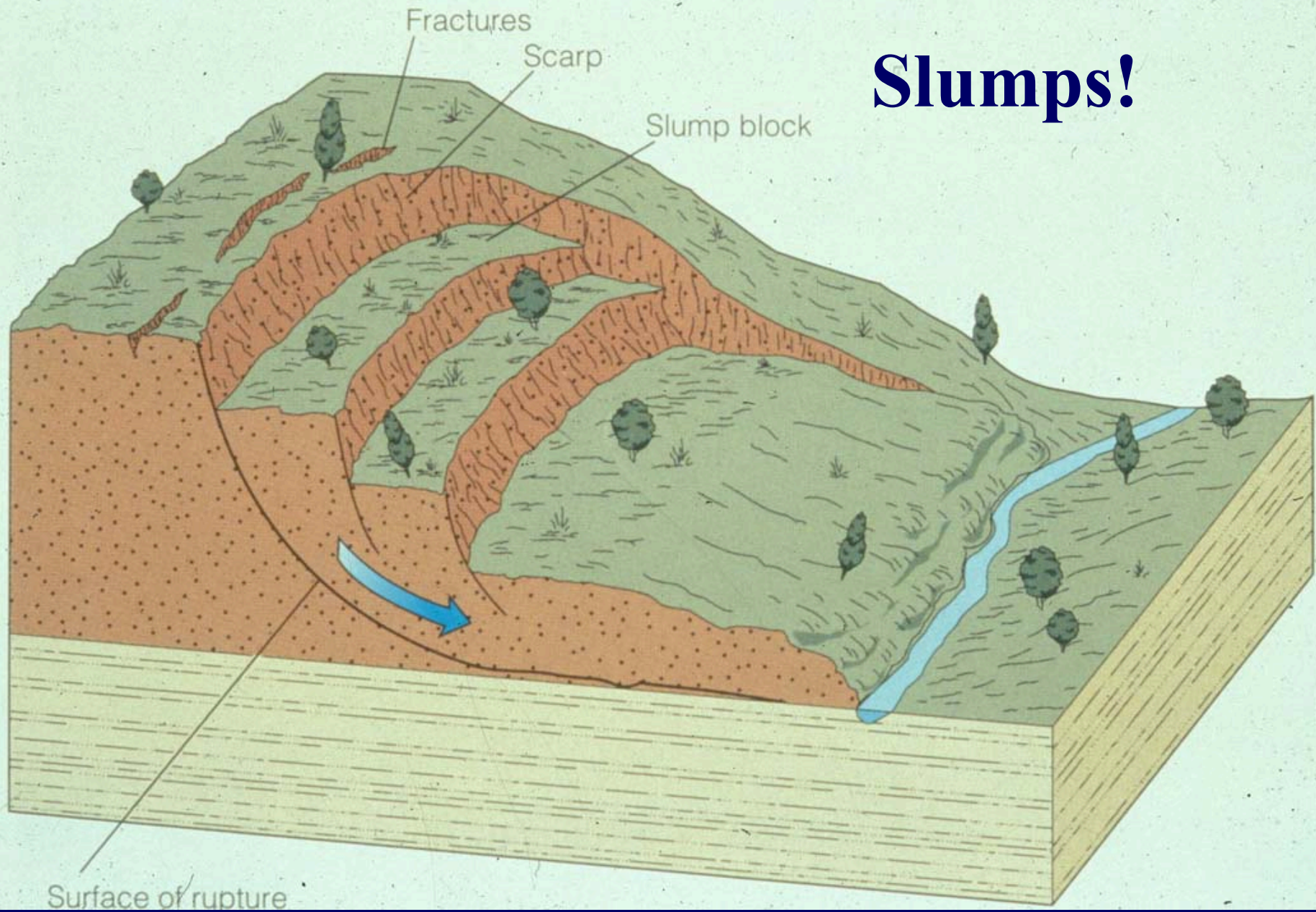
Ronda slide: Switzerland



Ronda slide

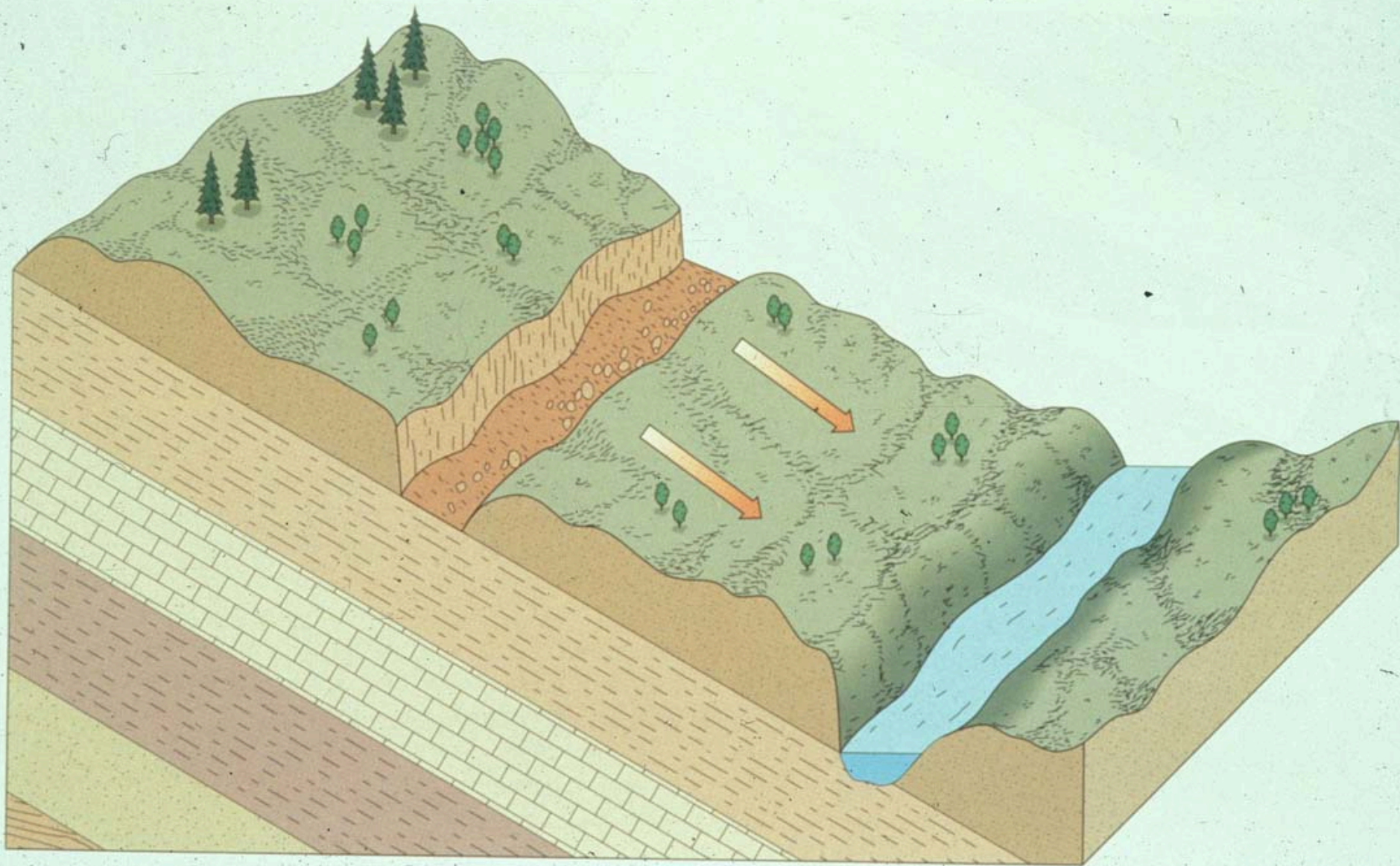


Slumps!






Slump



Translational Slide diagram



Leysin, Switzerland



THE GROS VENTRE SLIDE

BEFORE YOU LIE THE REMNANTS OF ONE OF THE LARGEST EARTH MOVEMENTS IN THE WORLD.

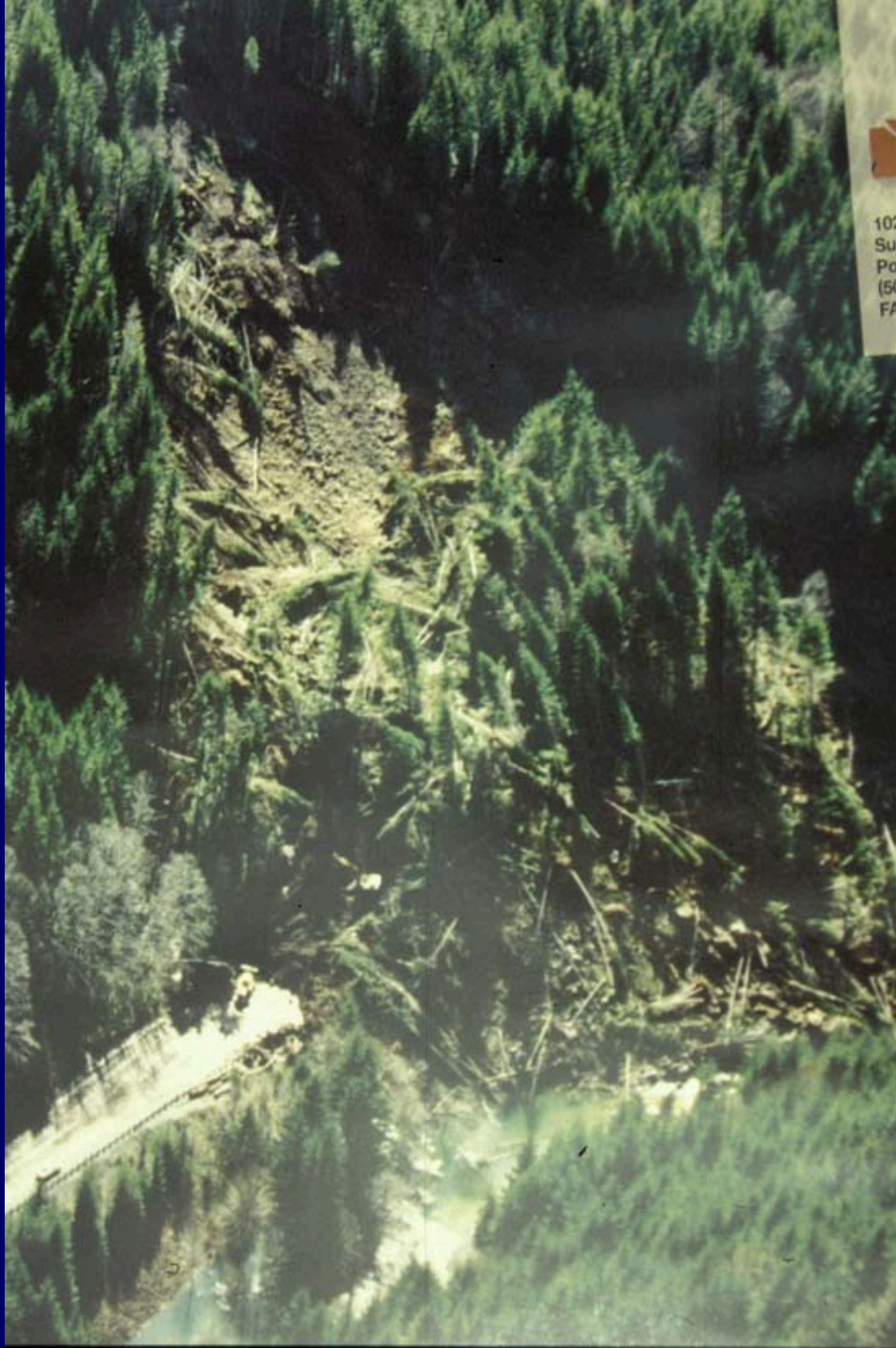
ON JUNE 23, 1925, EARTH, ROCK AND DEBRIS MOVED RAPIDLY FROM AN ALTITUDE OF 9000 FEET, ACROSS THE VALLEY BOTTOM AND UP THE SLOPE OF THE RED BLUFFS BEHIND YOU. THE ACTION LASTED ONLY MINUTES BUT A RIVER WAS DAMMED AND THE LANDSCAPE CHANGED.

GROS VENTRE SLIDE GEOLOGICAL AREA

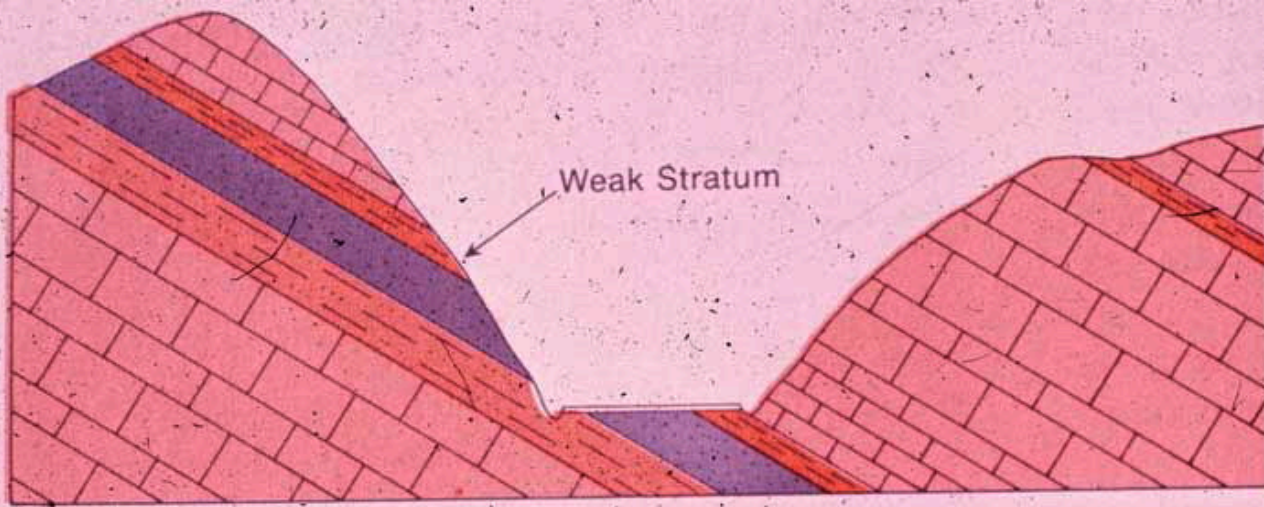


Gros Ventre landslide - Wyoming

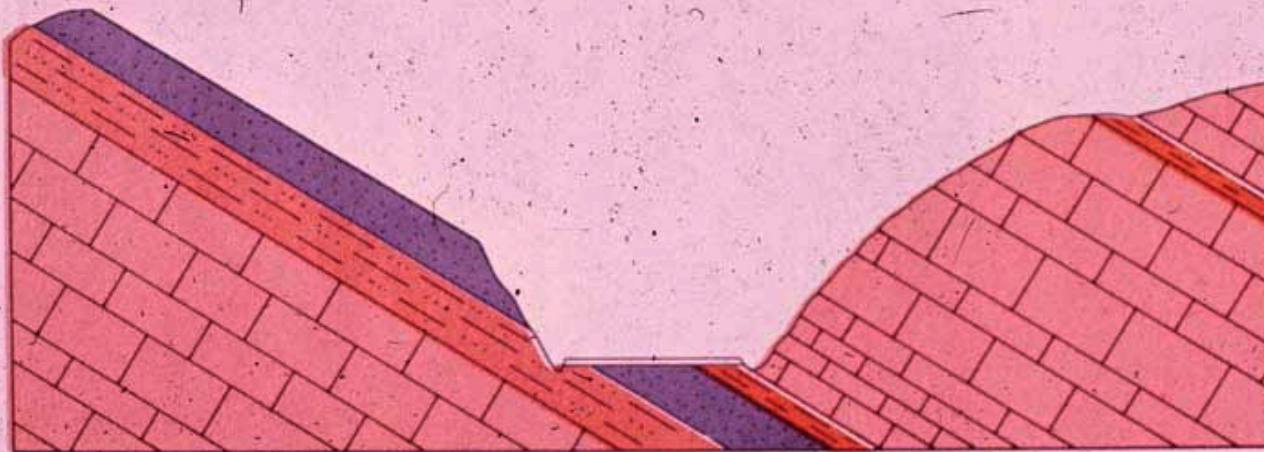
**Wilson
River
Highway
Oregon
1992**



MP 31 slide



Unstable Roadcut



Stable Roadcut

Figure 13-25 -

Removal of rock mass above potential failure so as to protect way from landslide.

Debris Flows

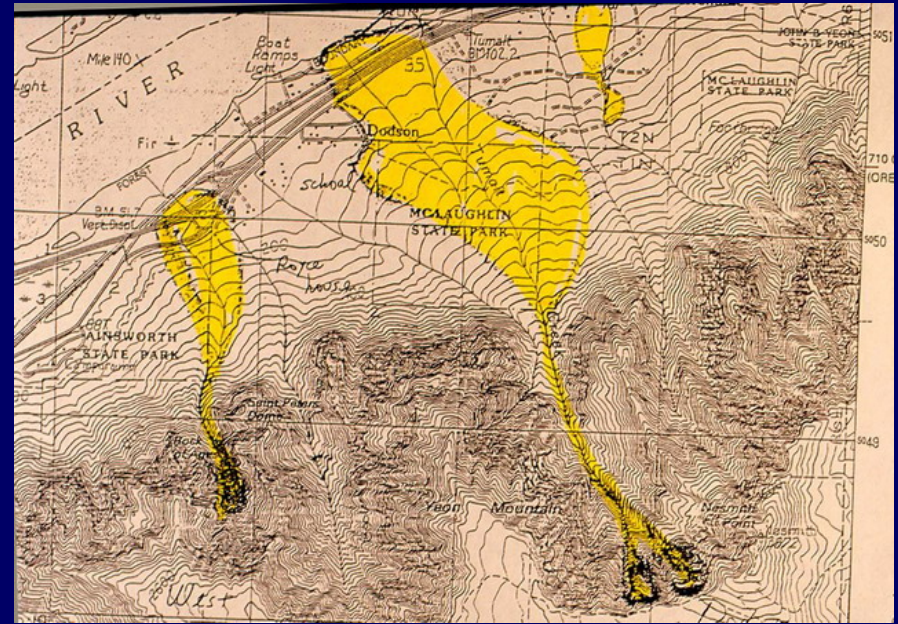


Dodson, OR, 1996: Royse Debris Flow (home) and Highway 84

Debris Flows



Dodson Alluvial Fan



Dodson Debris Flows

Debris Flows



Dodson: 1996 Tumalt Creek Debris Flow (35 mph)



Dodson, MP 35 Debris Flow December, 2001

Debris Flows Can Be Deadly



Douglas County
Debris Fan Home



Douglas County
Valley Bottom Home





Debris flow



Debris flow – dam broke above Estes Park, Rocky Mountain N.P.



Debris flow in Rocky Mountain National Park

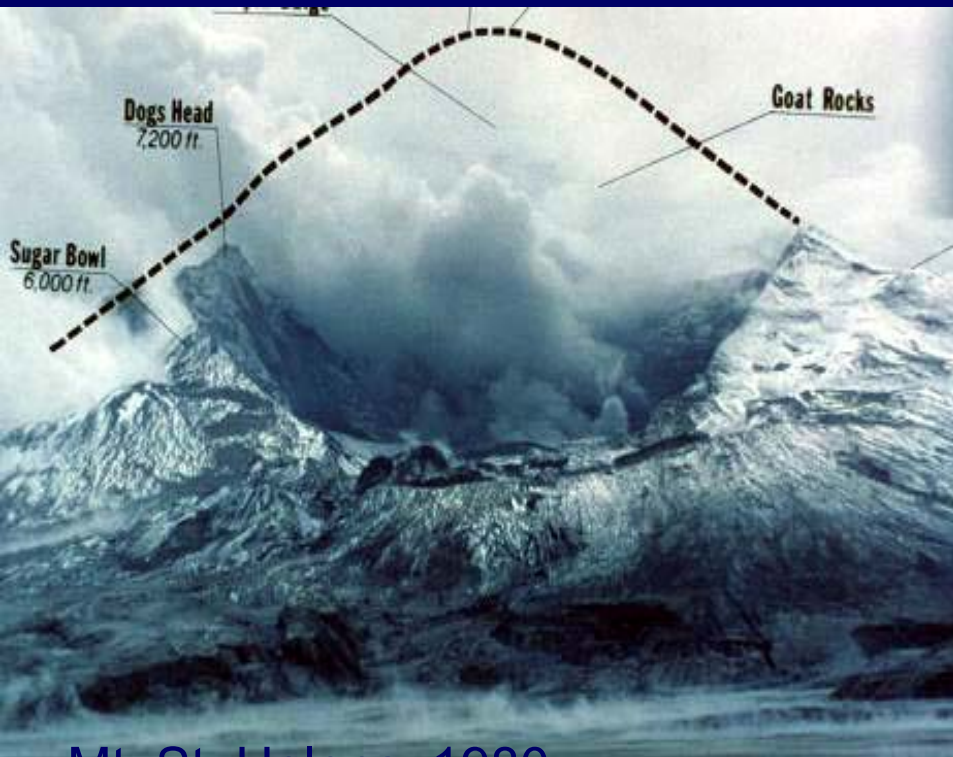


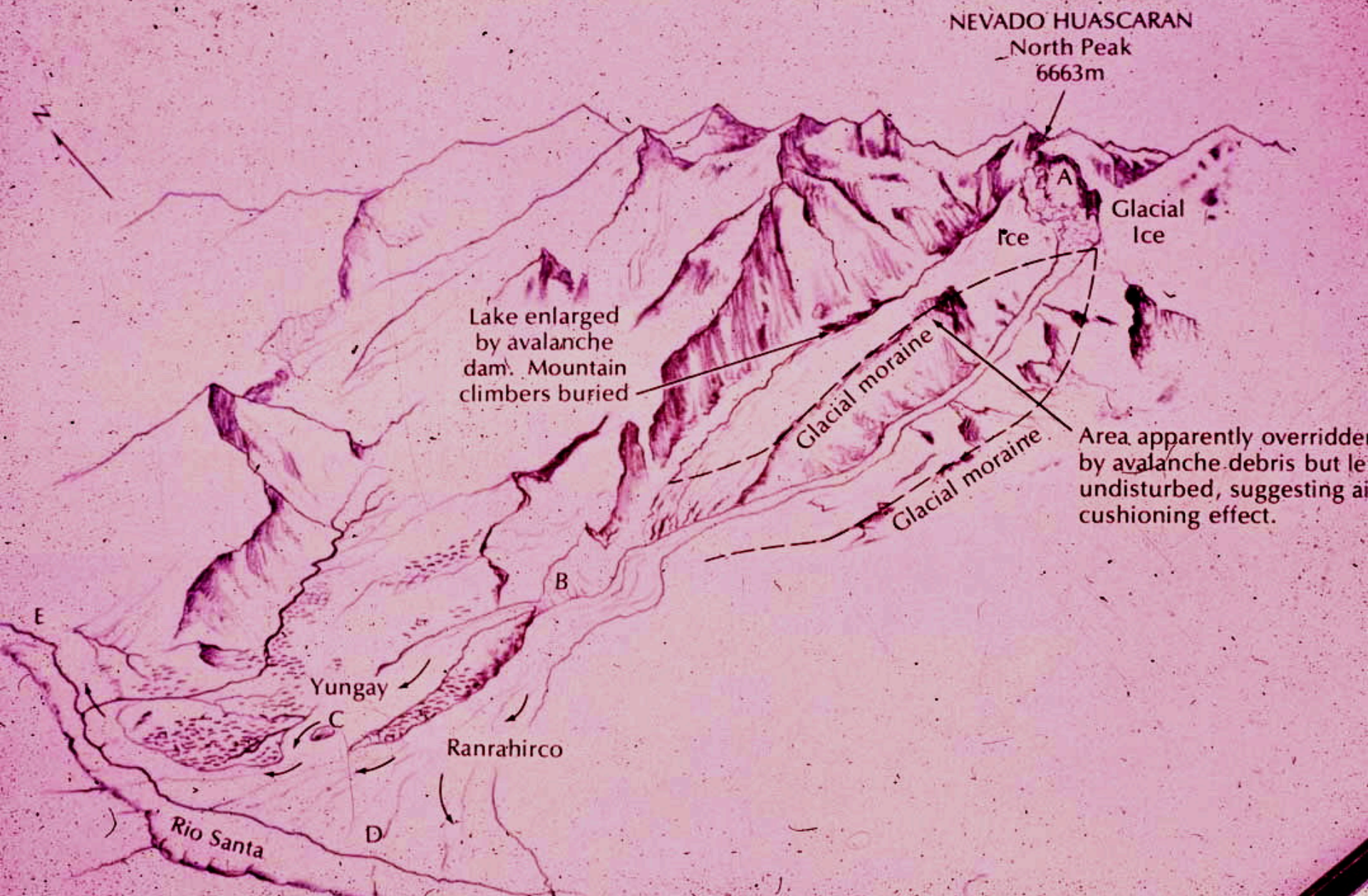
Earthflow in altered volcanic rocks - Merci River, south central Idaho

Fig. 124. Shallow landslide on shaly slope in the Puente Hills of southern California.

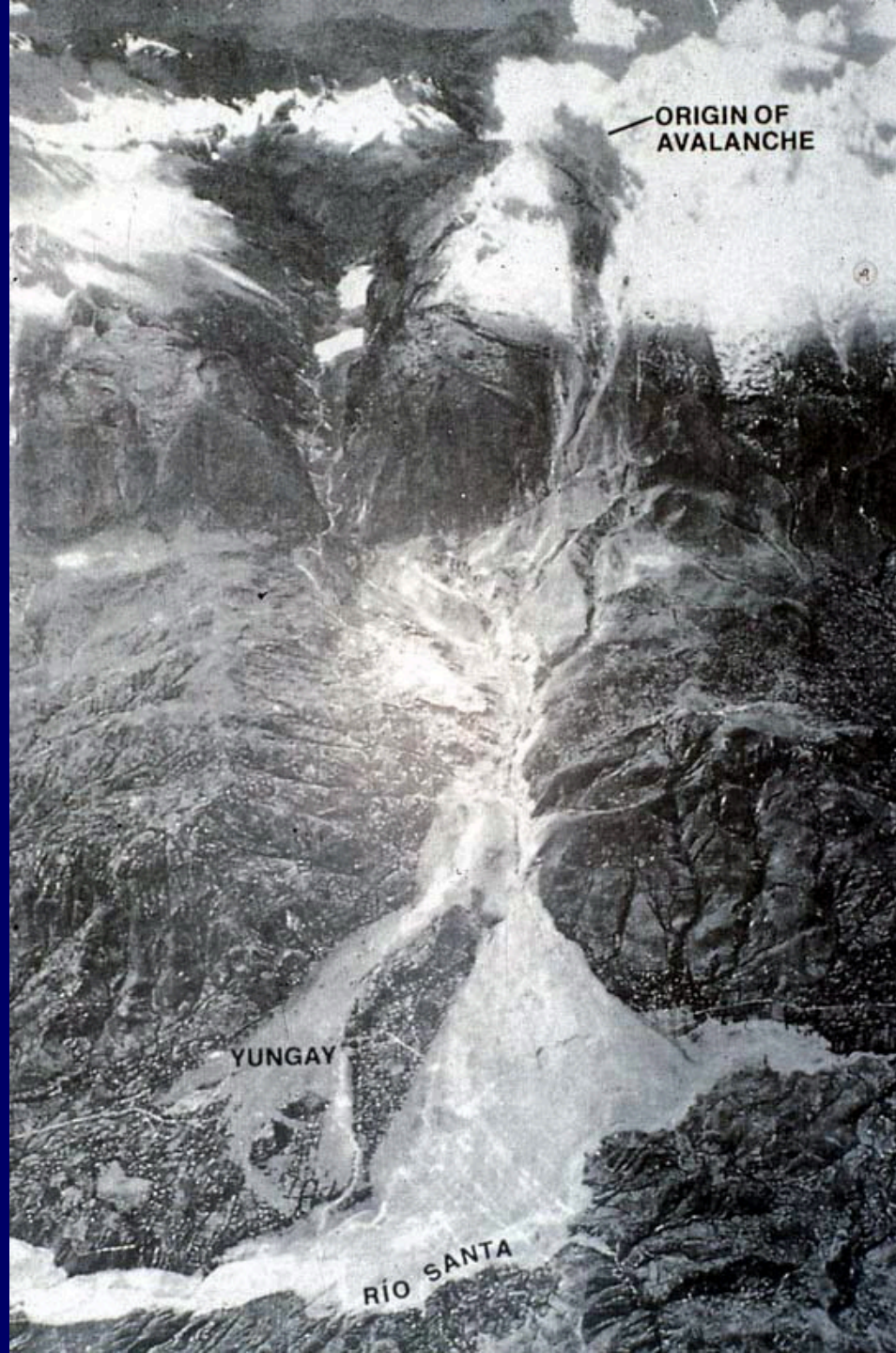


Volcanic Hazards = Importance of Debris Avalanches





Rock avalanche – Yungay, Peru – only area not hit was cemetery



Yungay had relocated
in 1900's out of
debris chute - 2
billion cubic ft of
rock



Debris Avalanches



Yungay cross on toe of entombed church



Landslide, ancient Flims

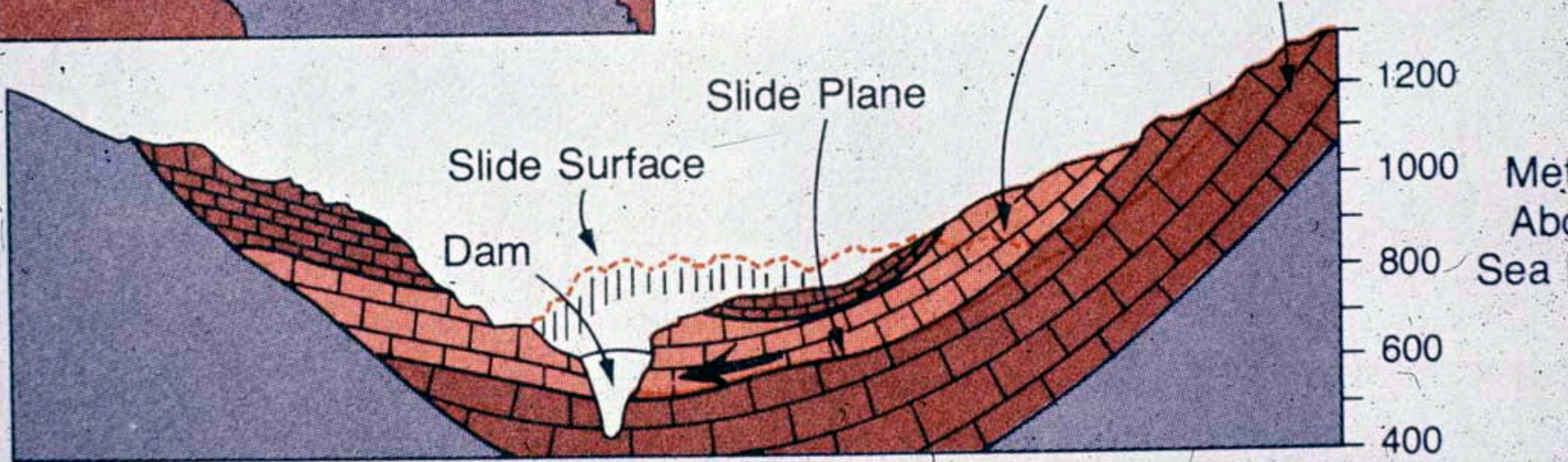


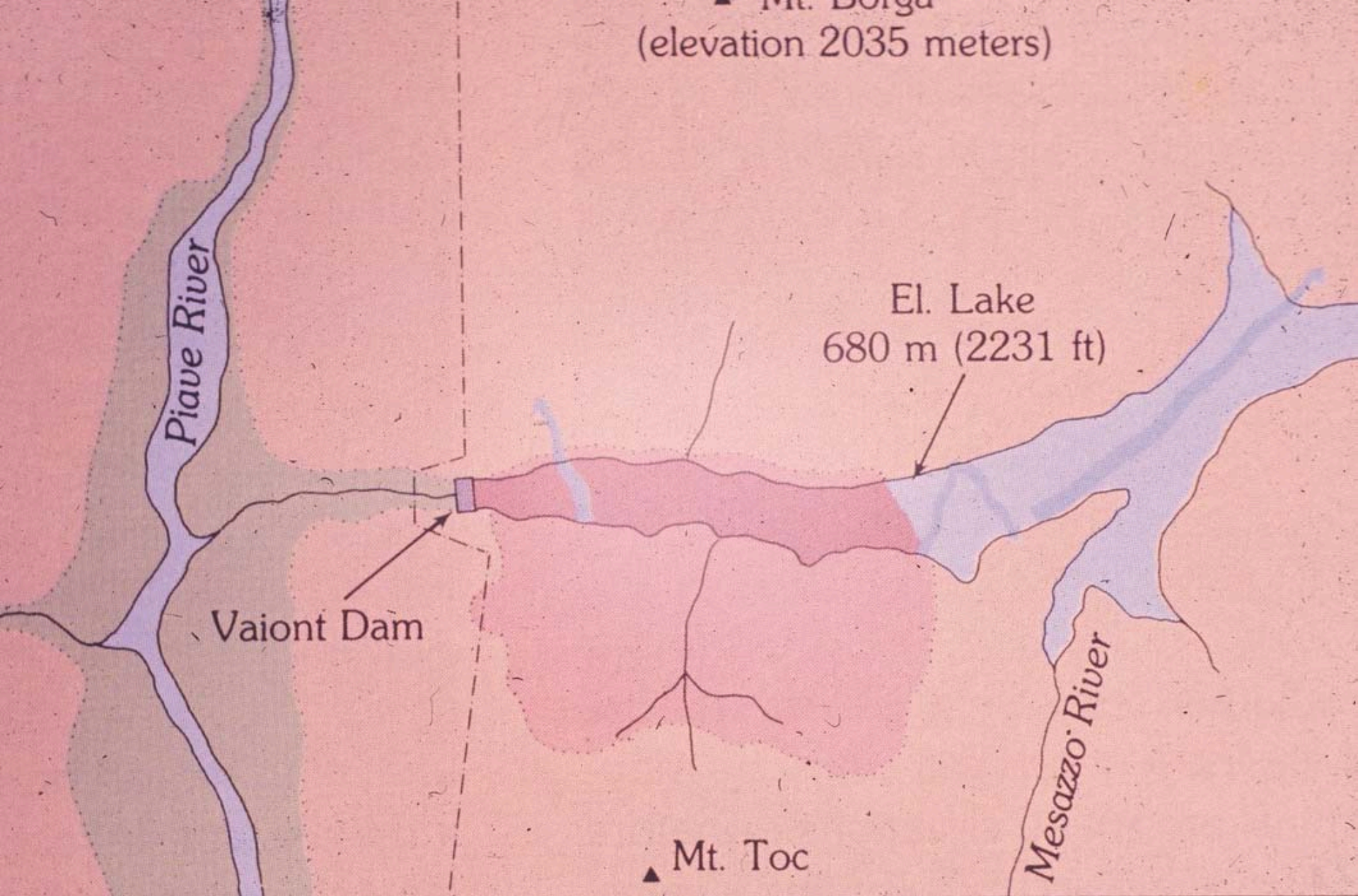
Mt. Shasta – 34 km away

Reactivation of Landslides



Cavernous Limestones
Interbedded with Thin Clay Layers





▲ Mt. Doriga
(elevation 2035 meters)

El. Lake
680 m (2231 ft)

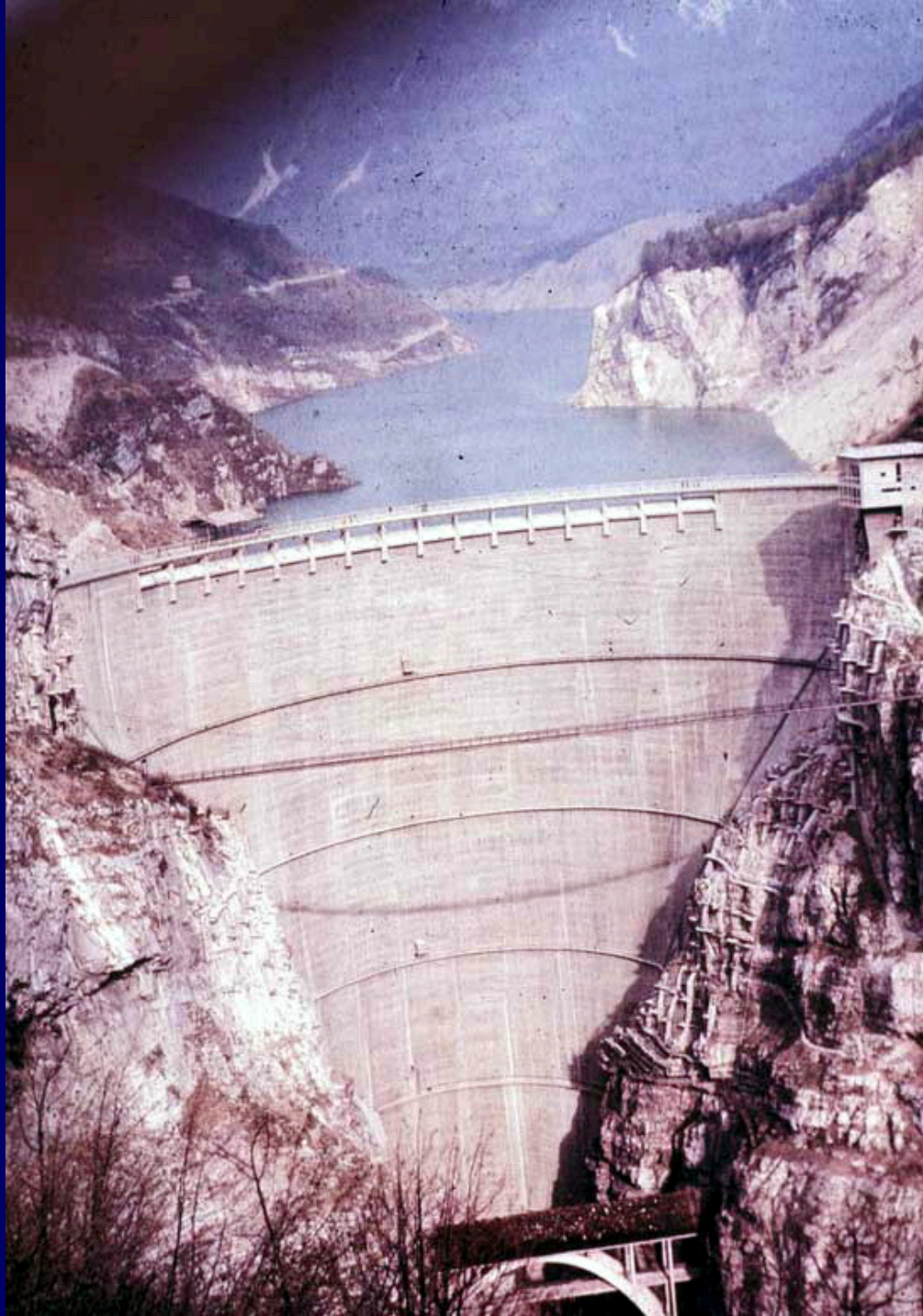
Piave River

Vaiont Dam

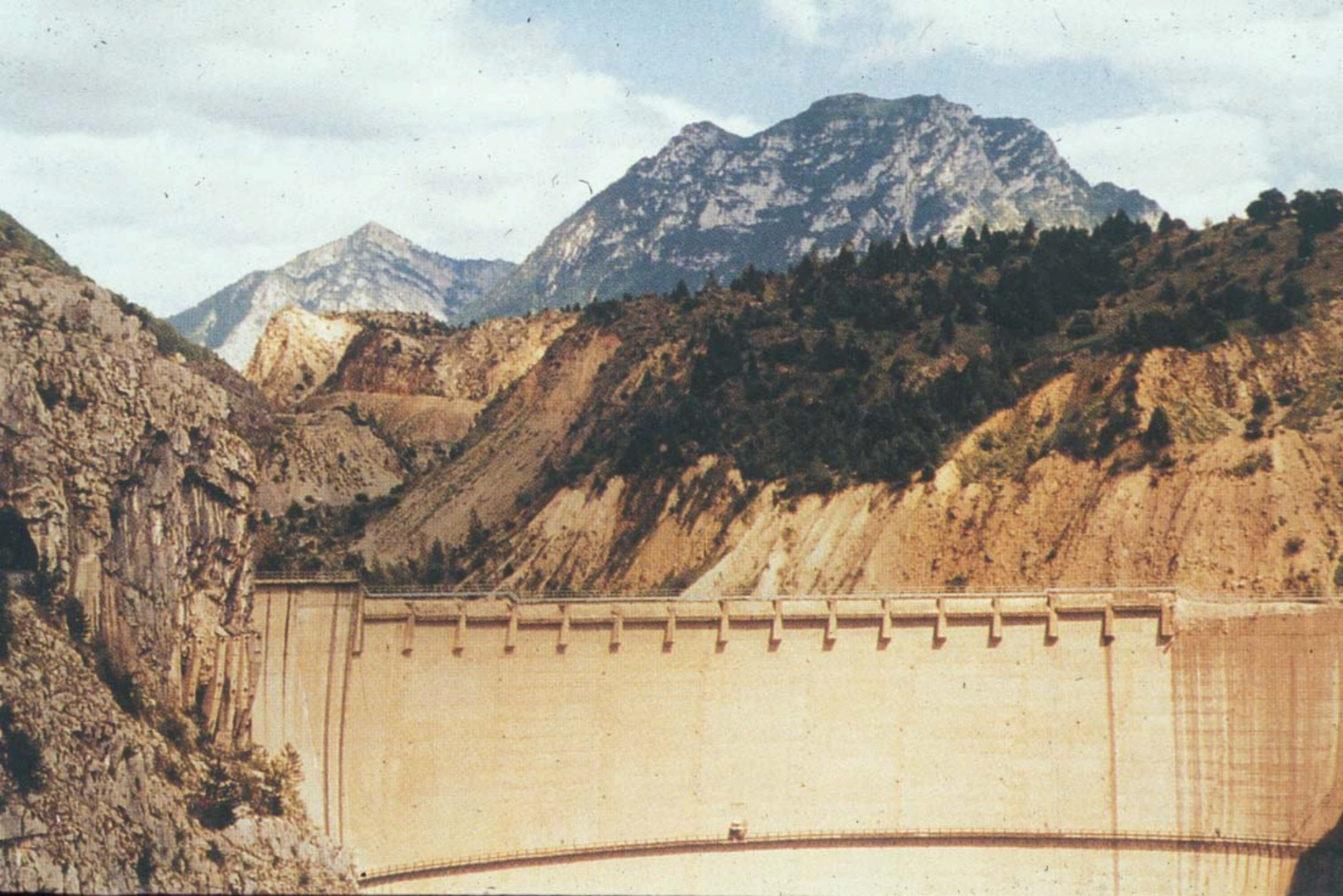
Mesazzo River

▲ Mt. Toc

Vaiont Dam limits of slide



Vaiont Dam flood - 8
billion gallons water,
2,200 killed



Dolomiten Vaiont Dam

Reactivation of landslide



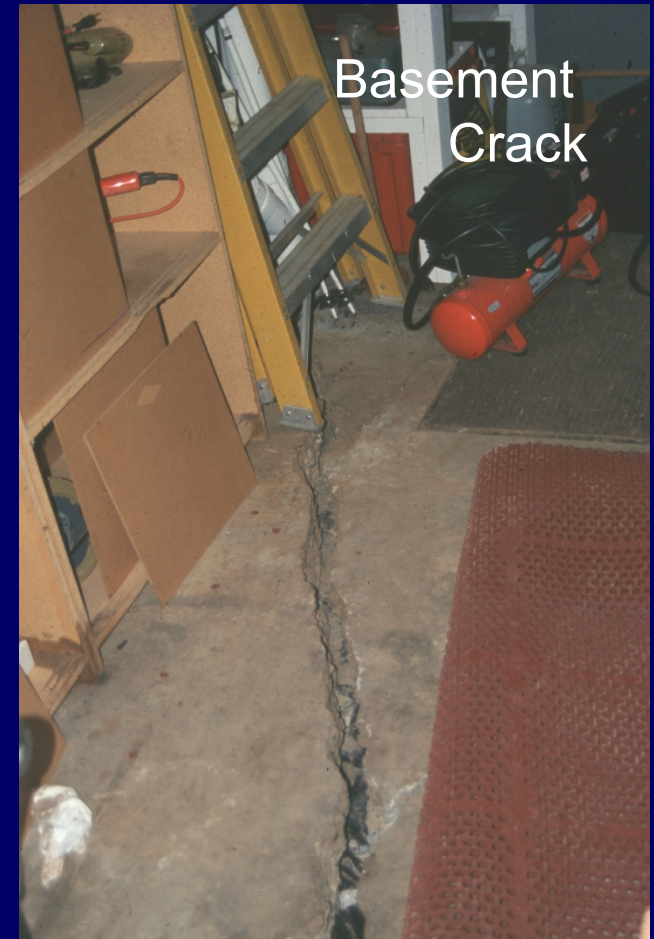
Matthew Court, Clackamas County

Troutdale Fm: Fluvial Deposits Reactivation of an old slide!



Holly Lane – Oregon City, Oregon

Reactivation of Landslides



Holly Lane, Oregon City, Oregon, 1996-1997

Reactivation of Old Landslides can be Significant



Building on the scarp



Building on the toe

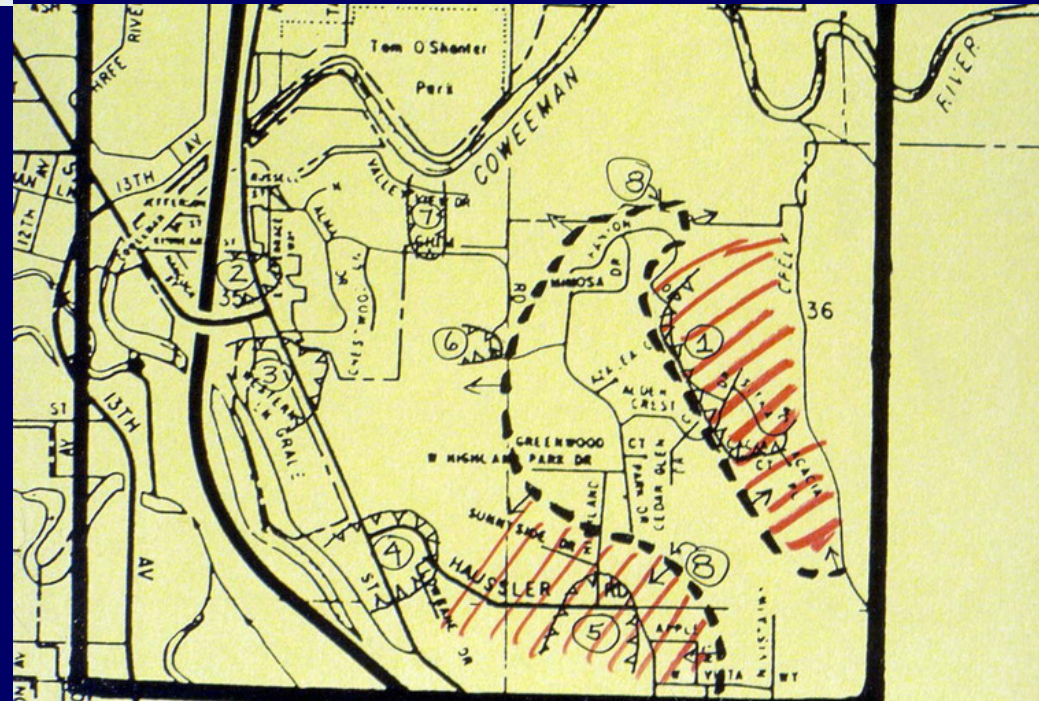
Reactivation of Landslides



Kelso, Washington

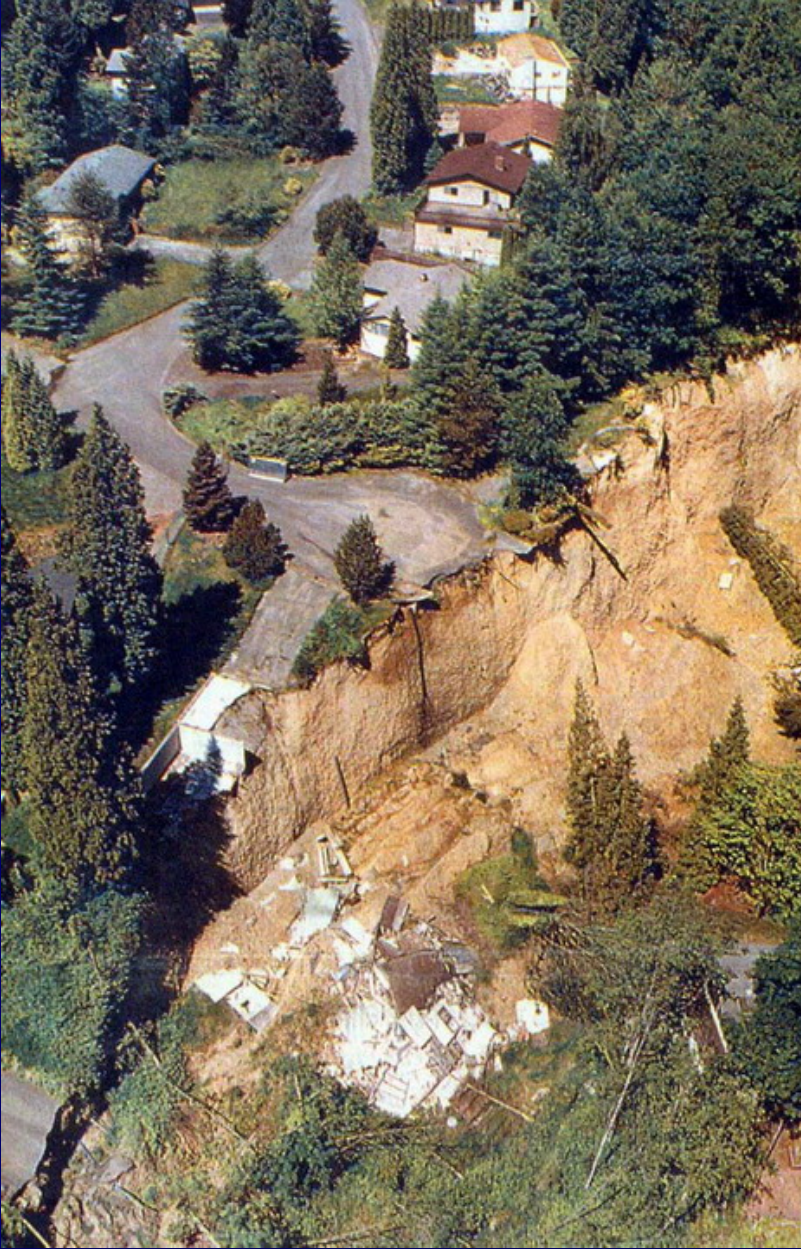
1998

Largest landslide
involving houses in
the United State's
history



Destruction

- 60 Houses destroyed on the lower slide
- 77 Homes sit uphill from scarp – “What do we do?”
- Costs: City infrastructure: \$6.2 Million
- Costs: Private property: \$25.7 Million
- FEMA: only gives 3.5% loans and helps city with infrastructure; rest of people lose everything



77 homes remain above scarp



60 homes destroyed

Kelso damage - \$25 million



Reactivation of Slides

Kelso: FEMA package was
about \$.30 on the dollar;
lawsuit failed against city





Kelso:
initially mapped as
“stable” area; fastest
movements where
storm drains

Reactivation of Slides





Kelso: FEMA package was about \$.30 on the dollar; lawsuit failed against city



2002

Newell Creek Apts.

Oregonian 10/05/2006



Newell Creek Apartments

Oregon City Jan 6, 2006

Newell Creek Apartments



Oregon City Jan 6, 2006

Jan. 6, 2006



Newell
Creek
Apts.

Jan 6, 2006





Newell Canyon



Old slide Jan. 6, 2006

February 15,
2007



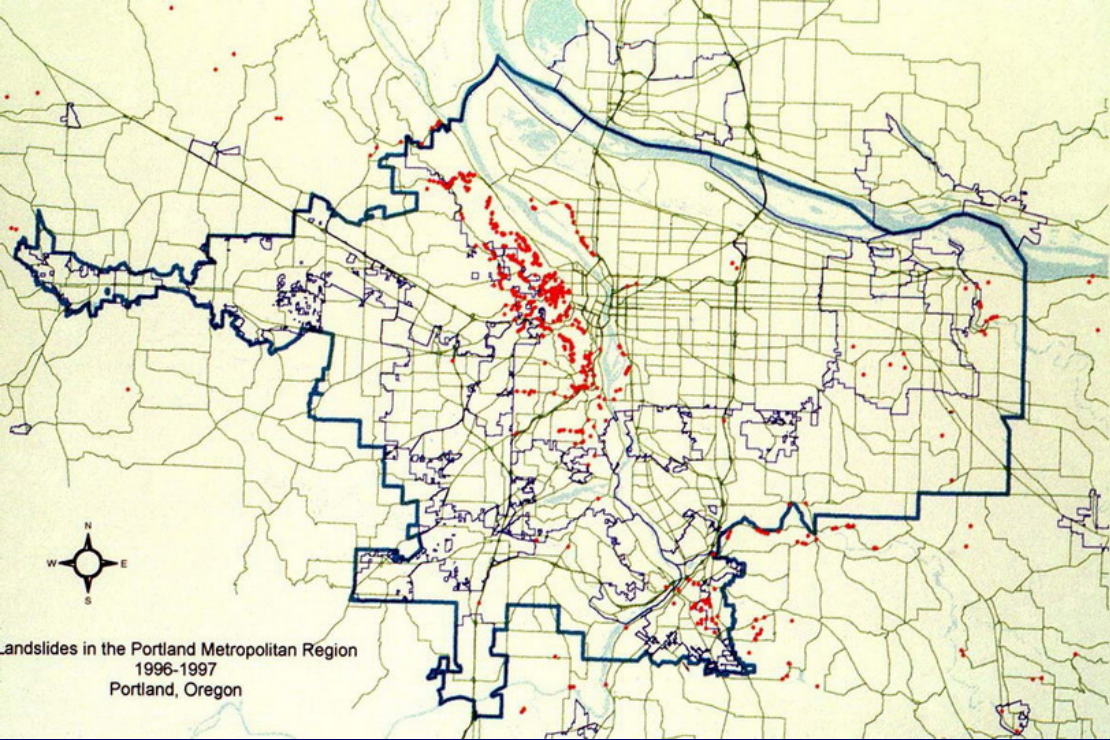
Driving Forces and Resisting Forces



CONTROL OF WATER

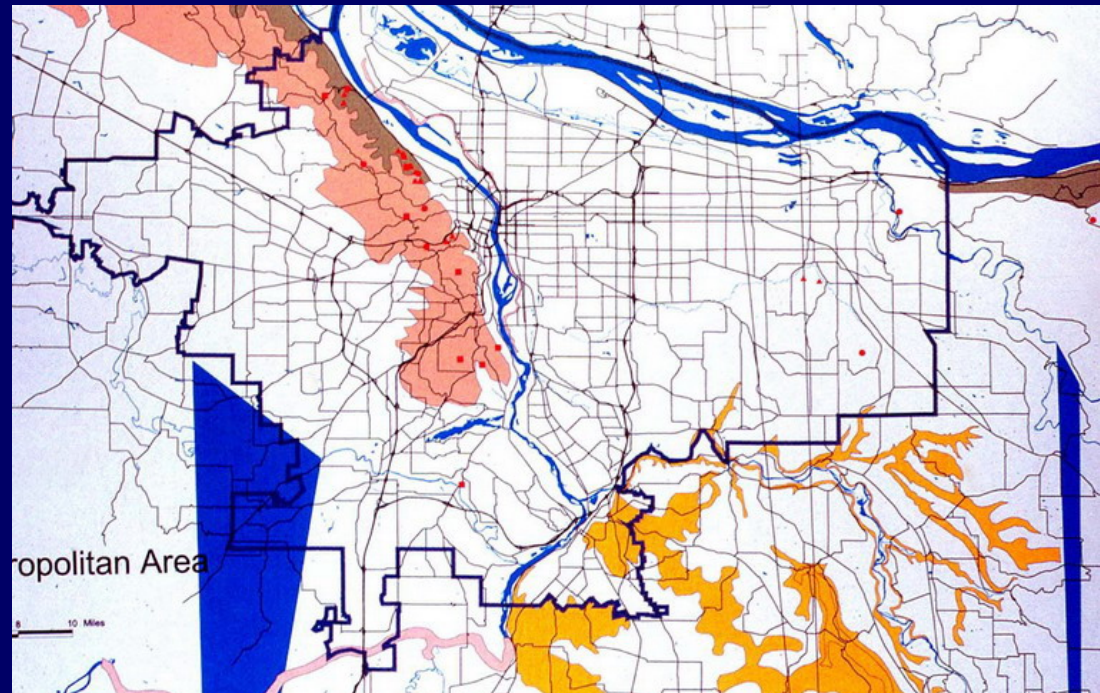
- Main trigger for landslides
- If you have two strikes against you and your house is in the “High” Susceptibility Zone, you need to control the water
- Are water removal systems working?
- After a slide – where did the water come from?

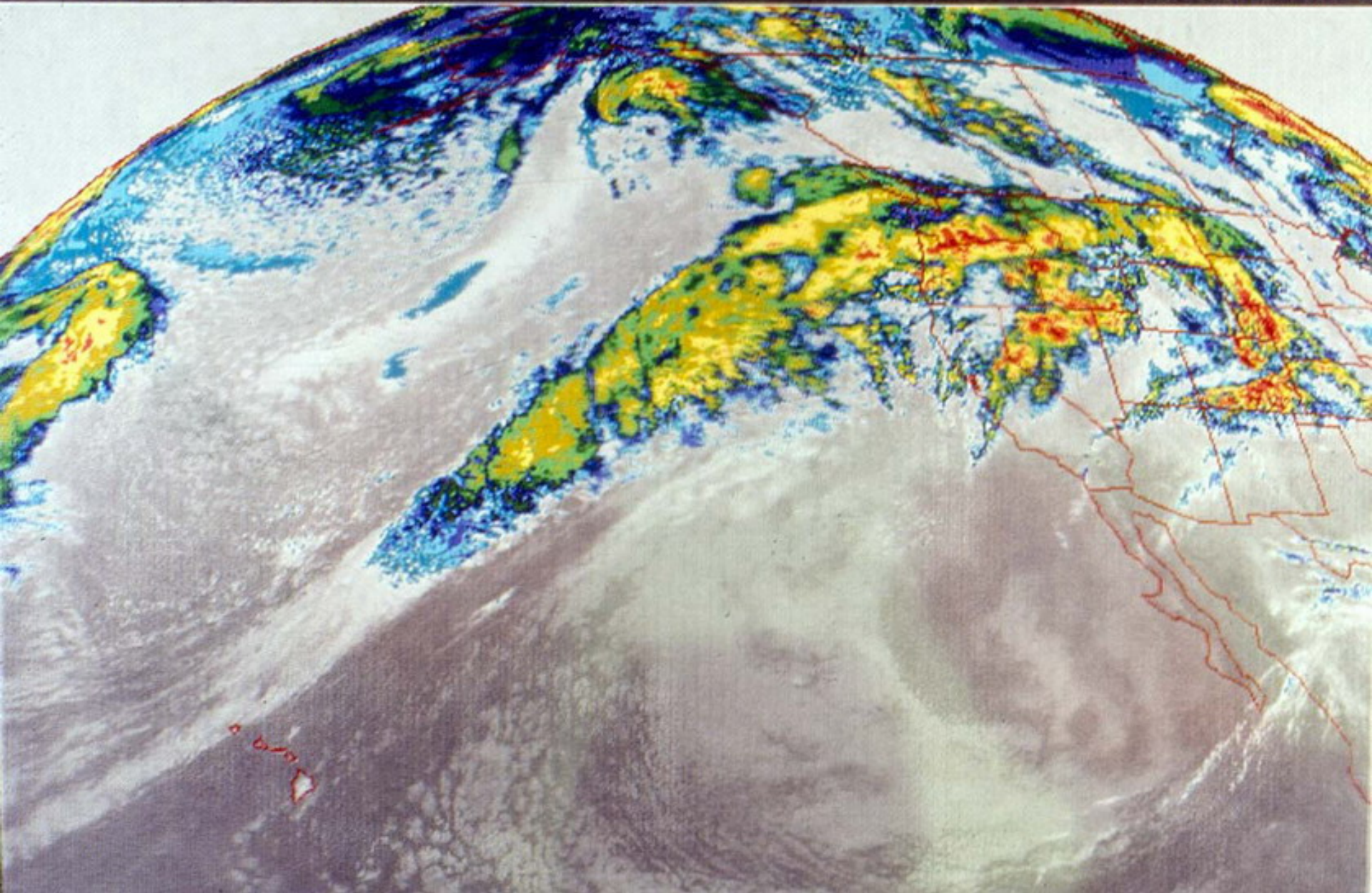
Portland, Oregon 1996



Landslides zones

**Landslide
Distribution**
Geology is important





Pineapple Express hits Portland

Loess: Earthflows



Calvary Cemetery

Human involvement can mitigate landslides



“City of Roses”
becomes city of plastic



The gutter resembled
Niagara Falls!

Human Involvement



Bureau of Environmental Services:
“Soaker Trenches for Storm Water



Street Drains Clogged: World’s
Fastest Earthflow at Pittock Mansion

Human Involvement



“There is a geyser in my front yard!”



Street Drains Clogged: World's Fastest Earthflow at Pittock Mansion

**Old sewer line
becomes
unplugged and
causes landslide
in Portland,
Oregon, 1996**



Fairmont





Mitigation is important



Gabion Walls – popular fix



Landslide before fix

Slide of February 1996: Earthflow



Parent Material: loess
Rainfall: 8 inches in 4 days

Vacant Lot : collected runoff
from upper road



Sometimes we recommend building on an old landslide



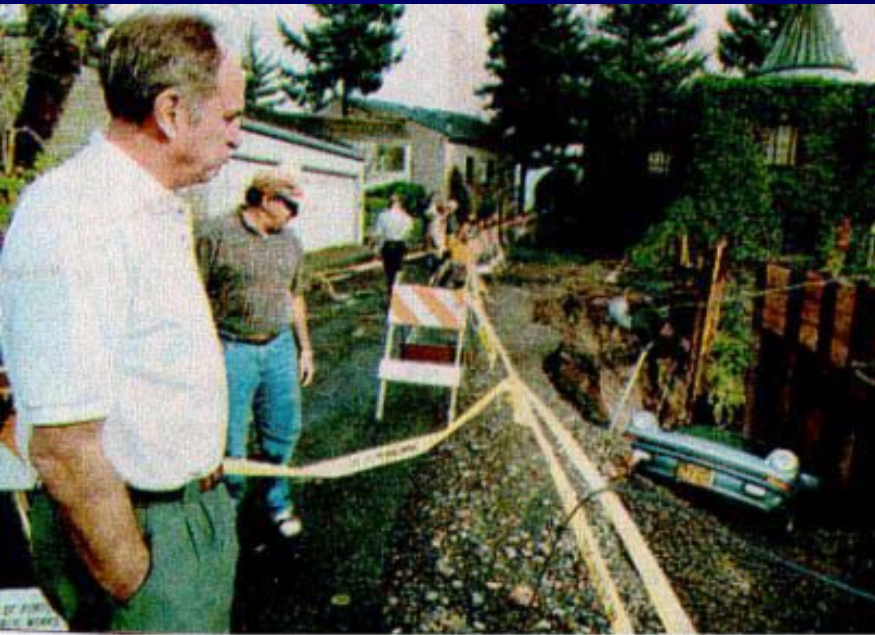
Wall built for \$70,000



Canterbury landslide source: water

1998 Landslide

They did not control the water -
The wall blew out and both
homes were endangered.
Froze ground!



Canterbury Castle



New Built on the site



Cardinell Drive



West Hills

December 2005



Cardinell Drive

First major slide
December, 2005

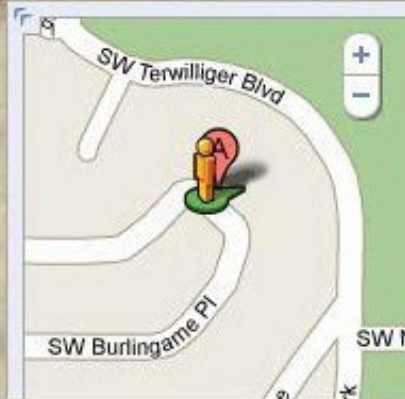
6436 **SW Burlingame Pl**, Portland, OR, United States
Address is approximate

Before

No Insurance!

SW Burlingame Pl

SW Burlingame Pl







October 8, 2008









January 1, 2009: 3" rain in 24 hours









Note Vegetation!



Importance of Using LiDAR



HIDDEN LAKE
ESTATES

Street of Dreams
Oregon City February, 2007



Fault and Shaking Photographs

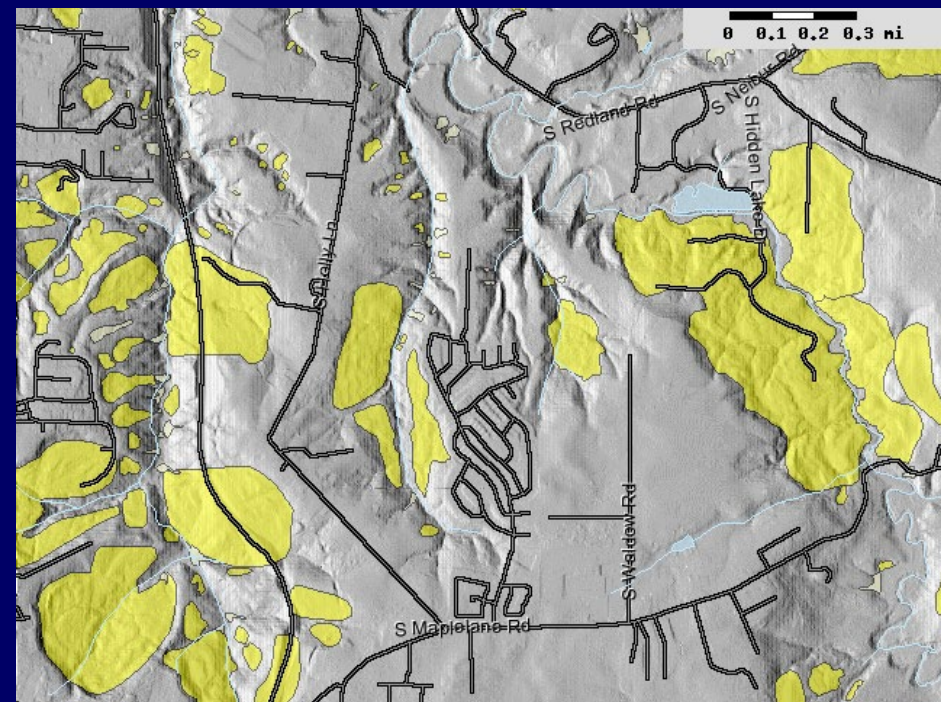
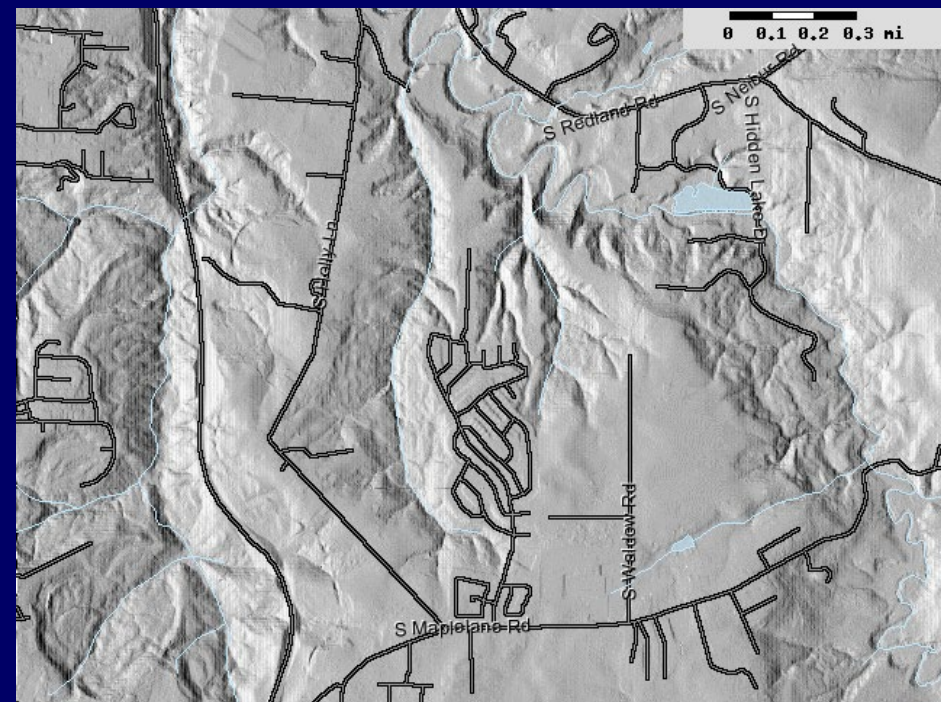
Probability for a M_w6.7 earthquake from 2003 to 2031



Fault locations are approximate



S Maple Ln Ct, Oregon City, Clackamas, Oregon 97045, United States



Yellow = landslide

February 17, 2007



February 17, 2007





February 17, 2007

February 17, 2007



February 17, 2007







**Lesson: Jury Selection of
another geologist**





Wall failure at Holiday Inn, Ruston after 12 inches of rain in two days



Removing landslide material from road, Sulphur Springs, Colorado

WENCHUAN EARTHQUAKE, MAY 15,2008, CHINA

- $M_s = 8.0$
- Total dead: 69,000
- 15 million houses damaged
- 35,000 landslides
- Beichuan City: 20,000 dead



New town

**New Beichuan
middle school**

Old town

Beichuan □ Buildings on both sides
of earthquake fault almost totally
destroyed □ about 20,000 fatalities.



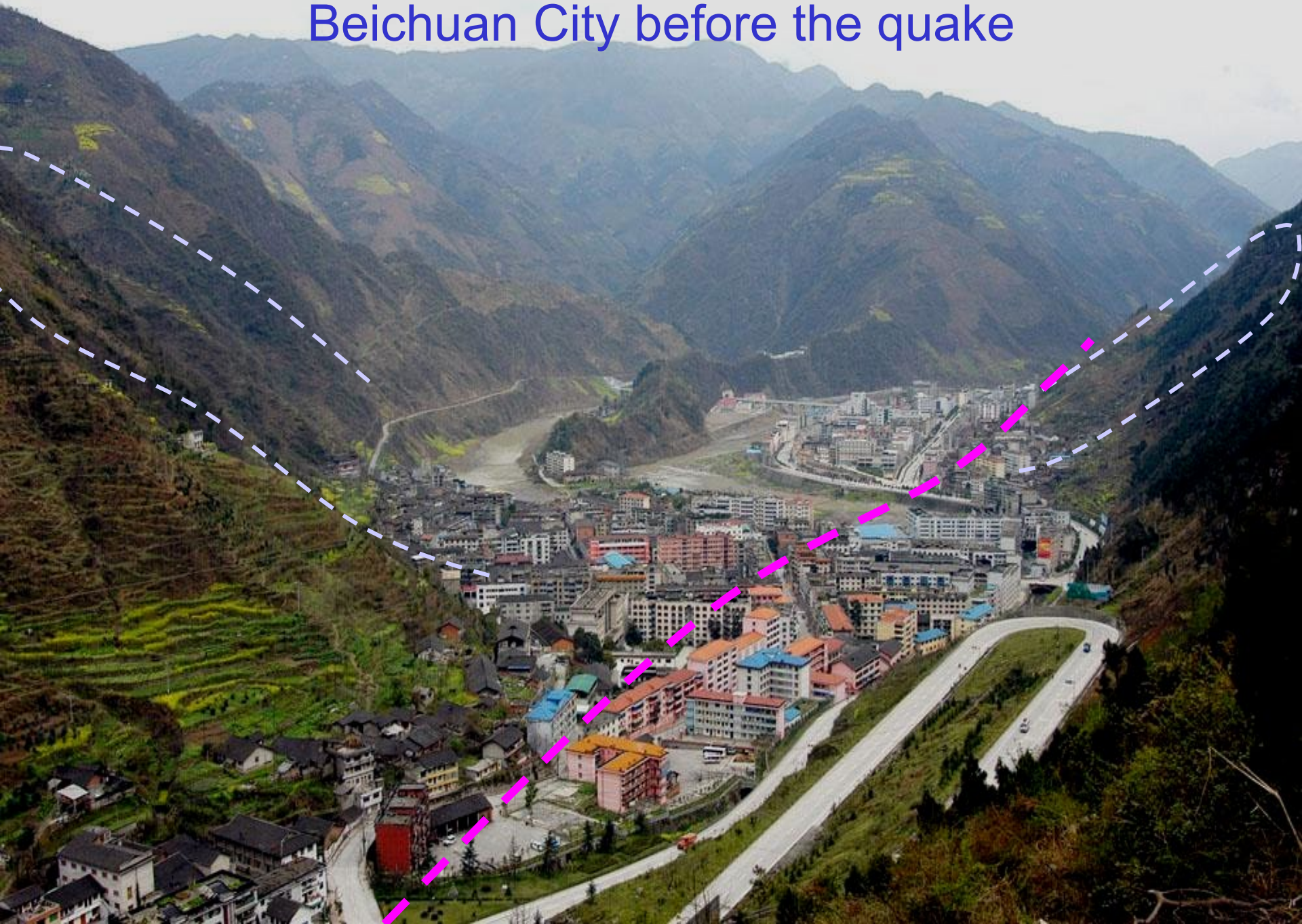
New town

New Beichuan Middle School Avalanche

Old town

Wangjiayan Landslide

Beichuan City before the quake



Beichuan county town after 9.24 debris flow



IMPORTANT FIRST STEPS: INVENTORY AND SUSCEPTIBILITY MAPS

- Phase 1: **Inventory Maps** – where were past slides, processes related to geology
- Phase 2: **Susceptibility Maps** – extrapolate principles from inventory maps to low, medium and high susceptibility zones
- Phase 3: **Risk maps** – need population density and usage of areas

BASEBALL ANALOGY OF FACTORS & LANDSLIDES

- Strike One: Slopes
- Strike Two: Weak Soils and Problematic Geology
- Strike Three: Trigger (Water or Quake)

Conclusions

- Determine the Factors & Processes
- Understand the geology and climatology
- Use the Big Three: Inventory, Susceptibility and risk maps
- Remember to ask: Is the slide a reactivation?
- Control of water is an important factor to prevention
- Earthquakes are also important factors