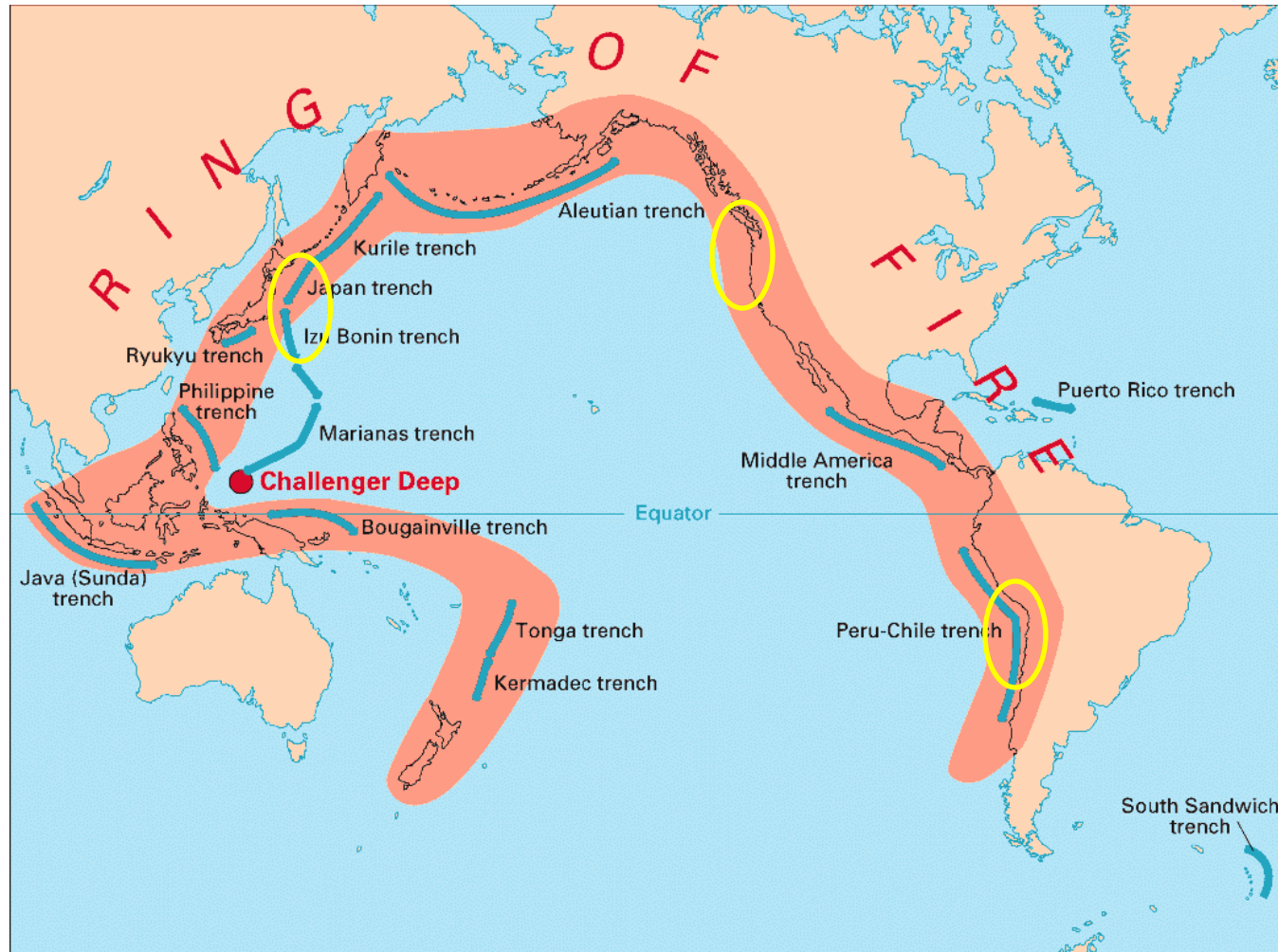
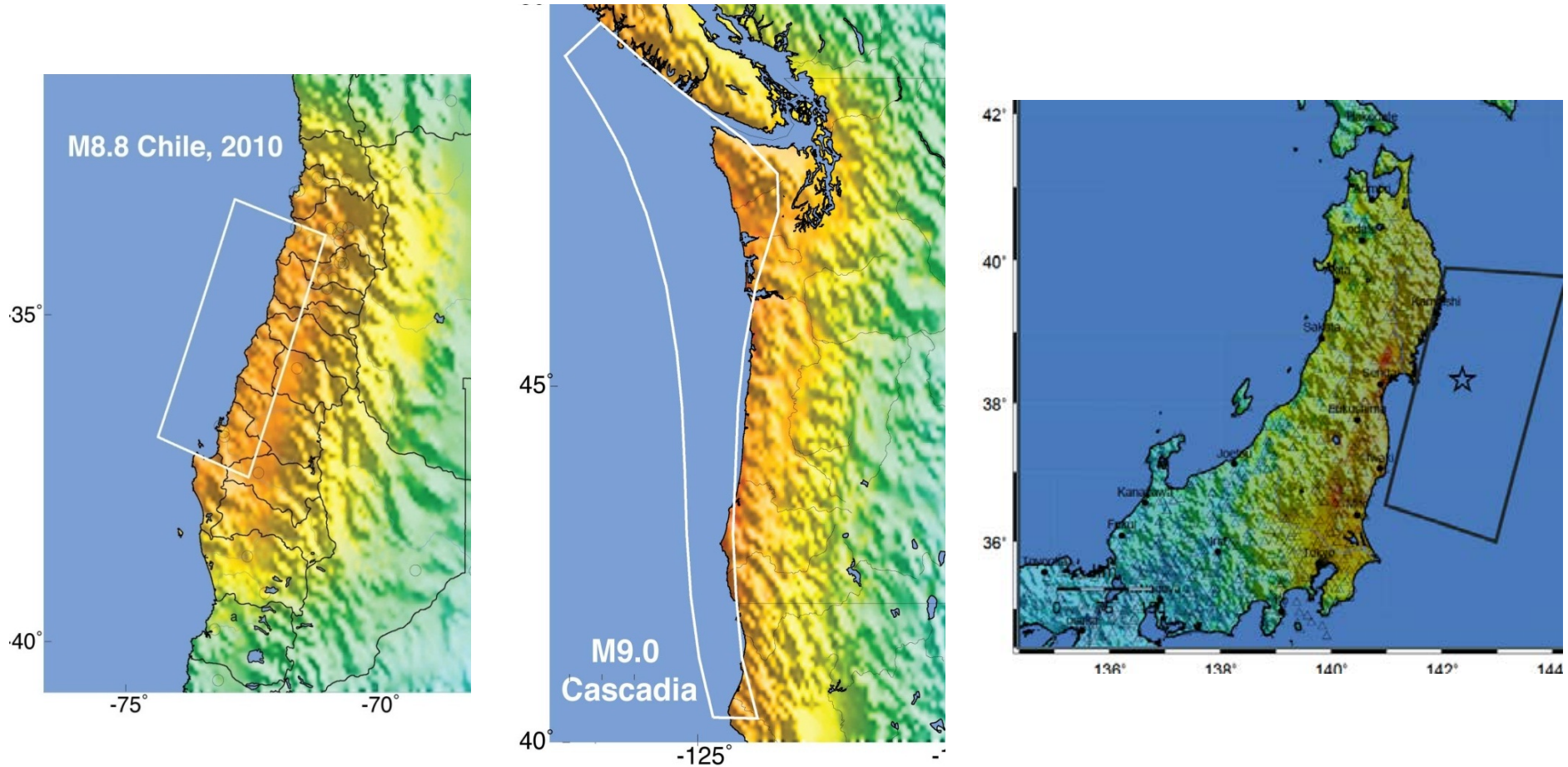


# Pacific Ring of Fire



# Comparison to Cascadia SZ and PacNW



# M9.0 Tohoku Japan

March 11, 2011

- >15,500 deaths, >3,500 missing (most a result of tsunami)
- 4th Largest Earthquake on record
- 500+ km Coastline effected
- Tsunami up to 38m in height and 12 km from shore (seven separate waves)
- 3 to 4 minutes of strong shaking (PGA of up to 3 g measured)
- Aftershocks up to M 7.9 (three over 7.0)

# M8.8 Maule, Chile

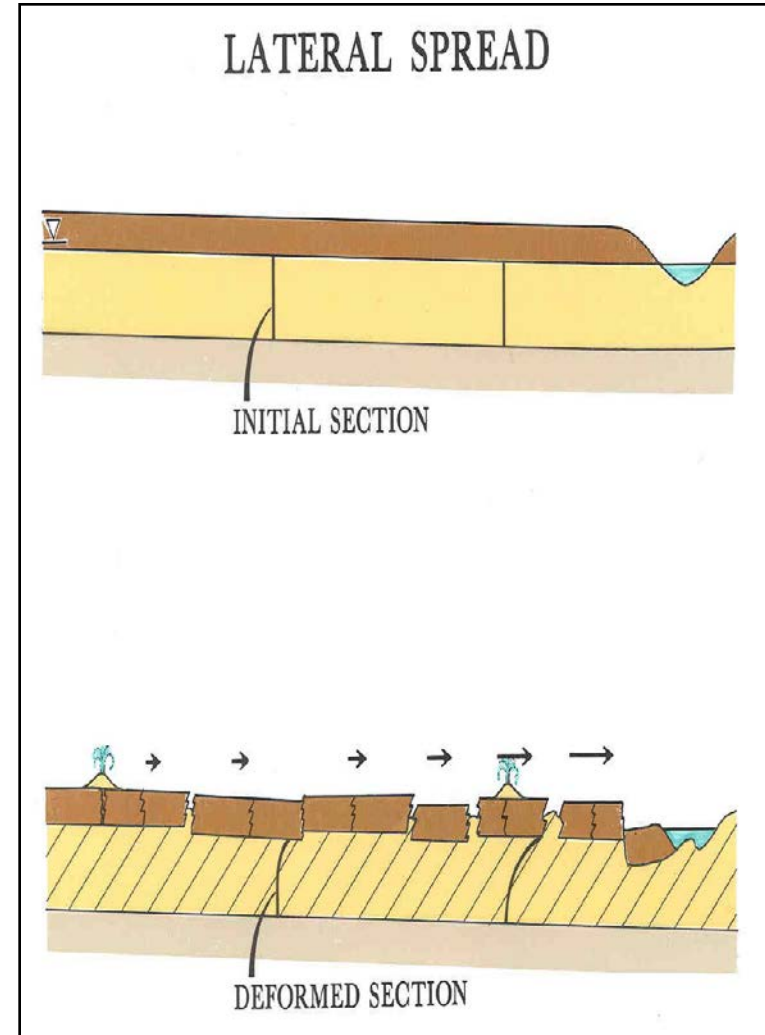
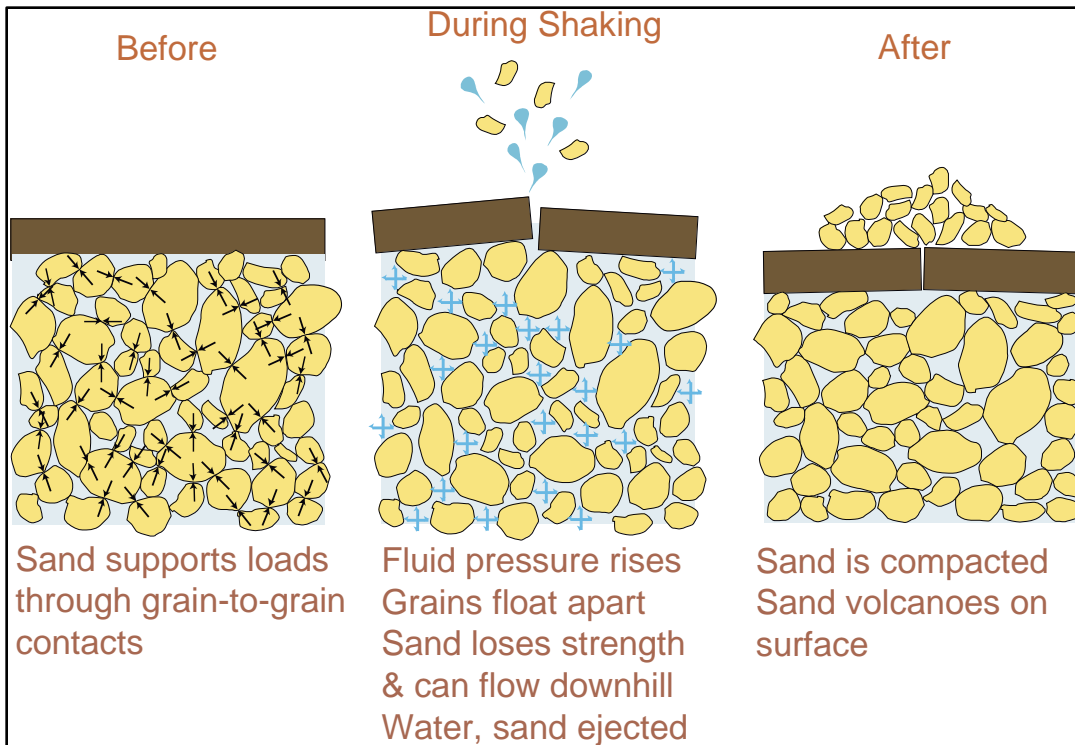
February 27, 2010

- 486 deaths, 73 missing (over ½ a result of tsunami)
- 6th Largest Earthquake to occur since 1900 (GEER - updated)
- 600+ km of Coastline effected
- Tsunami up to 20m in height and 6 km from shore (three separate waves)
- 1 to 1.5 minutes of strong shaking (PGA of up to 0.65 g measured)
- Aftershocks of up to M 7.2

# Observed Damage Patterns

- Shaking Damage
  - Weak Soils
  - Weak Infrastructure
- Tsunami Damage

# Liquefaction & Lateral Spreading



# Ground Shaking Damage

## Weak Soils





# Ground Shaking Damage

## Weak Soils







# Ground Shaking Damage

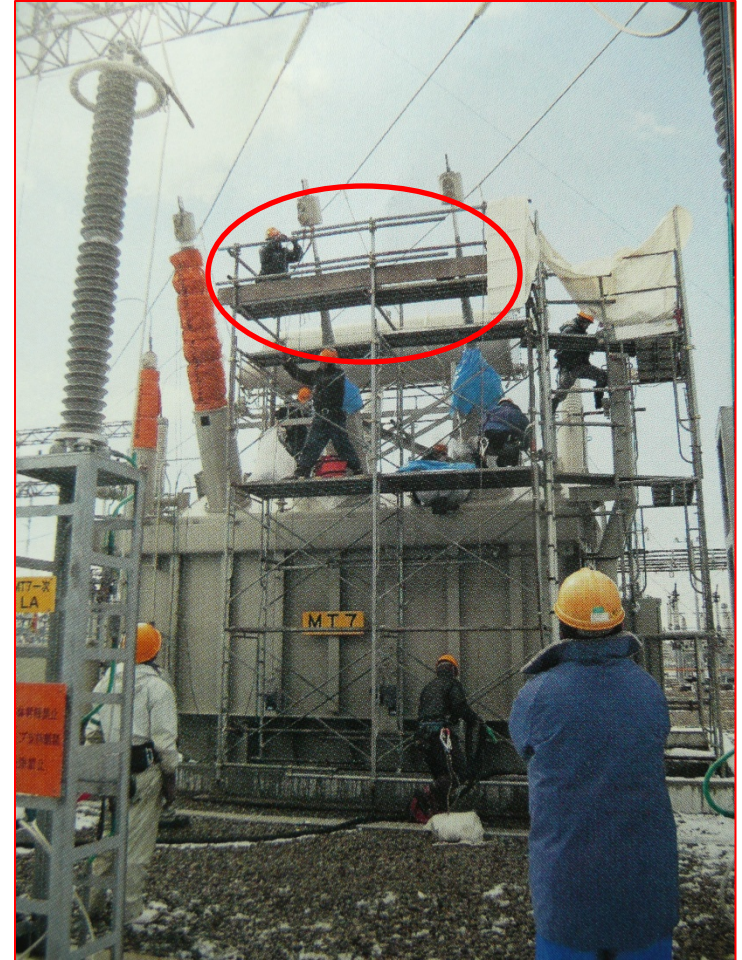
## Landslides





# Ground Shaking Damage

## Weak Infrastructure





# Tsunami Damage



被災前  
・撮影年月日:平成22年



被災後  
・撮影年月日:平成23年3月

# Tsunami Damage





# Key TCLEE Observations - Japan

1. Recovery of the Electric Power grid access was timely (6 days, 90% – 10 days, 95%)
2. Significant percentage of damage was caused by the Tsunami
3. Transmission line tower performance was typical to other earthquakes (Liquefaction and Landslides)
4. Nearly IMPOSSIBLE to protect open air, ground level, substations against a Tsunami (Water & Tsunami impact)
5. High level of shaking damage to High Voltage Electric Power Transformers
6. Distribution System Failures: Tsunami impact, and typical failures from Landslides, Liquefaction, Pole mounted transformers, Unanchored equipment
7. Power Plant Problems (along the coast) Tsunami related, no/to very little information on actual failures of components from ground shaking (e.g. Soil failure of penstock)



# Transportation

## Poor Soils – Embankment Failures





# Transportation

## Weak Infrastructure





# Liquid Fuel

