

Great Earthquakes of Peru

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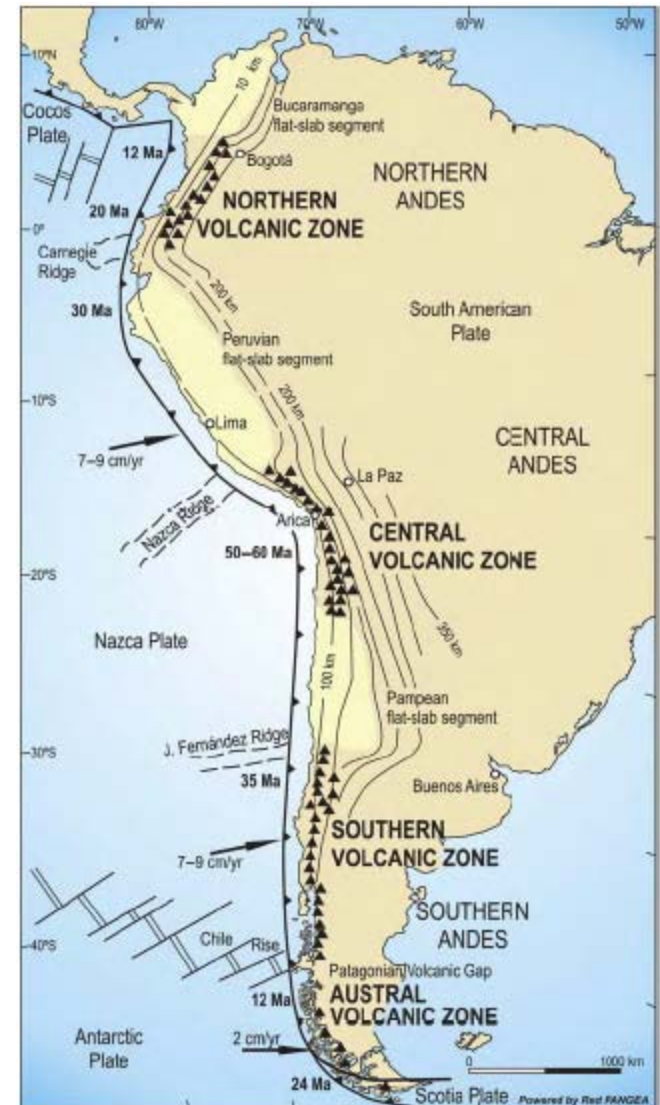
Major Themes

Natural Hazards

- Earthquake history & recurrence intervals
- Tsunami risk

Subduction Zone Science

- Temporary & permanent upper plate deformation
- Plate coupling (percentage of seismic vs. aseismic slip)
- Stress transfer, earthquake nucleation, rupture processes
- Fault segmentation



Historical Subduction Earthquakes

Lima: Founded 1535,
destroyed by
earthquakes in 1586,
1687, and 1746.

Pisco: Founded 1640,
destroyed by tsunami in
1687, 1746, and 1868.

Arequipa: Founded 1540,
destroyed by
earthquakes in 1604,
1687, 1784, and 1868.



2001 Mw 8.4 Arequipa Earthquake

- Major damage to Arequipa
- Locally destructive tsunami killed ~80 people
- Fault slip offshore; no fatalities from building collapse



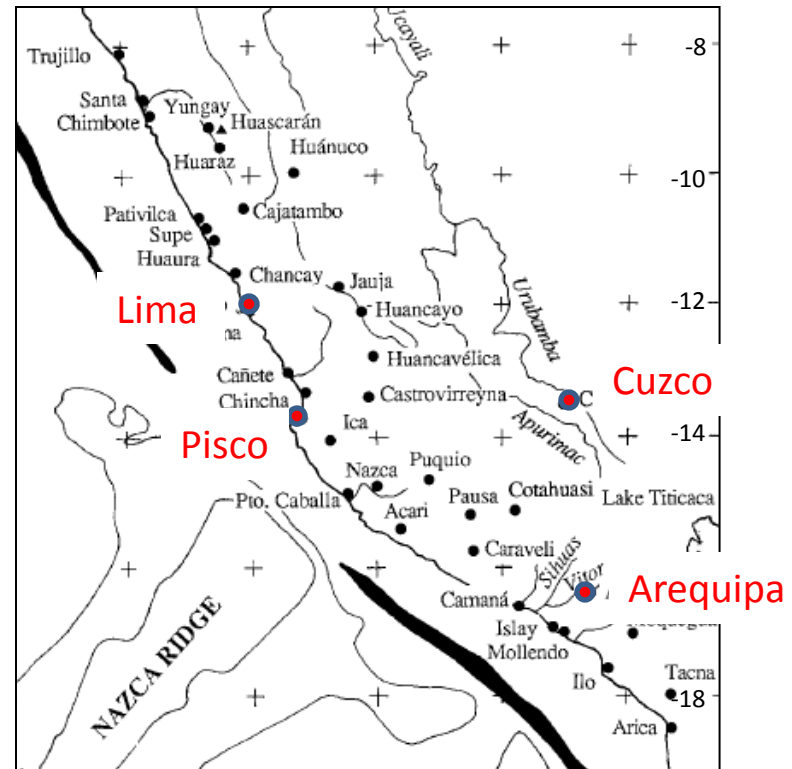
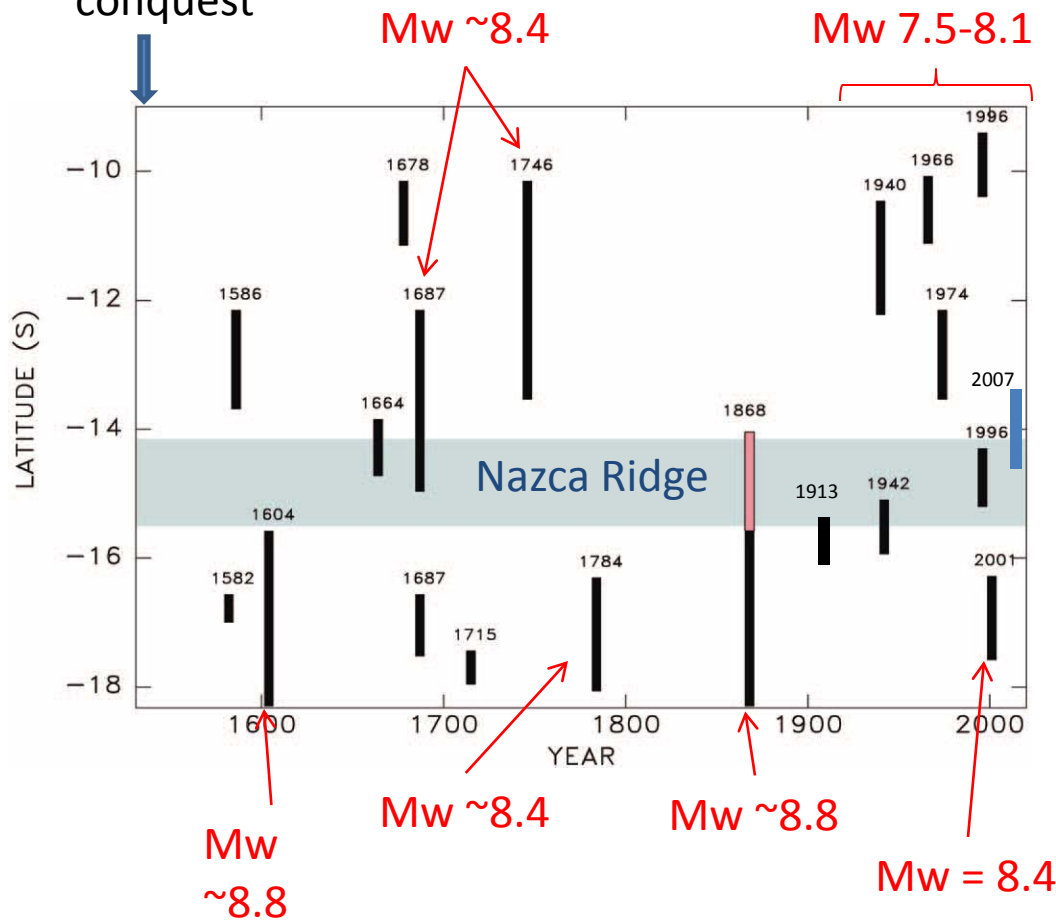
2007 Mw 8.0 Pisco Earthquake

- Fault slip directly below Pisco
- Severe damage to Pisco area
- More than 500 fatalities
- Locally destructive tsunami
- Ongoing controversy regarding government response & recovery



Central & Southern Peru

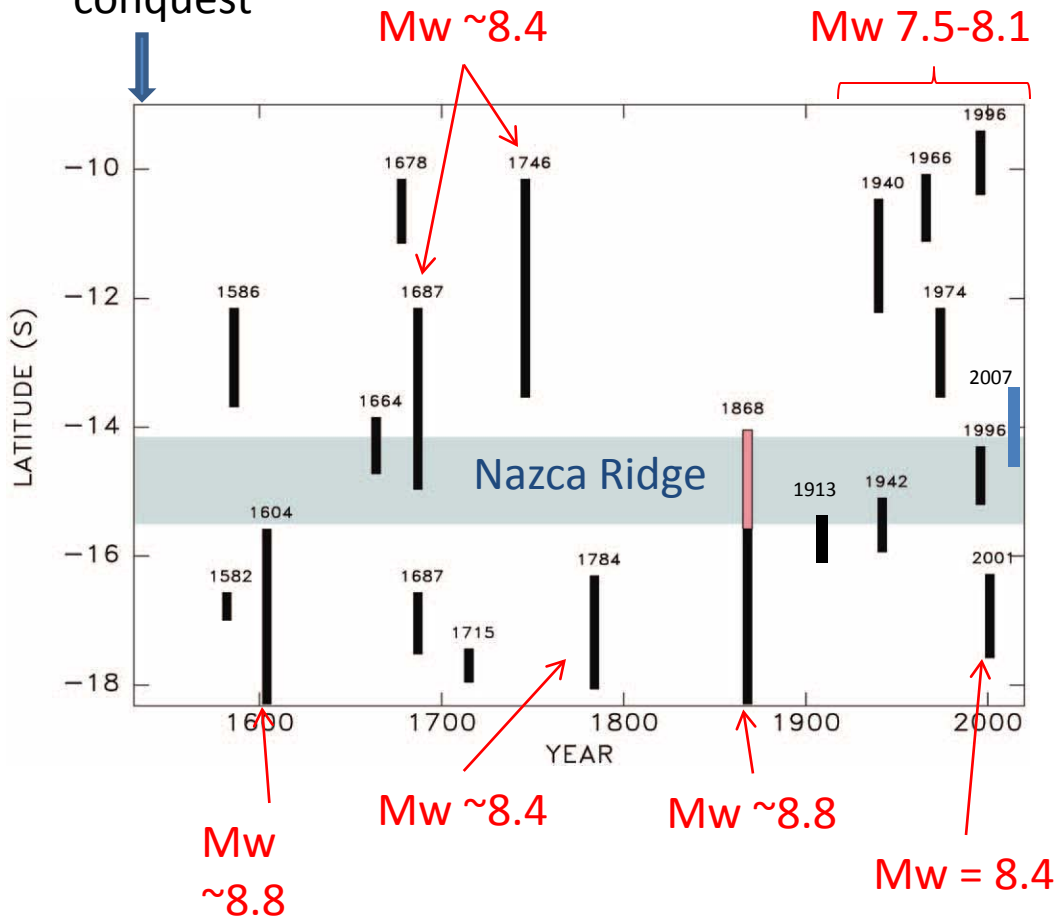
1530s:
Spanish
conquest



(Dorbath et al. 1990; Okal et al. 2006; Pritchard & Fielding 2008)

Segmentation?

1530s:
Spanish
conquest

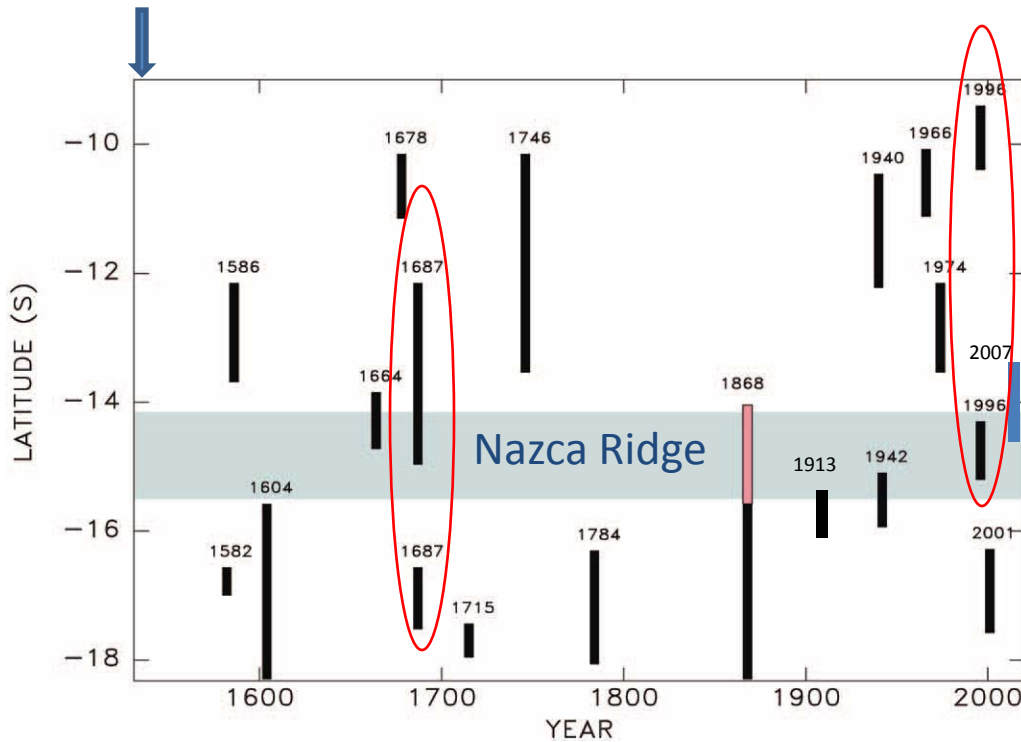


- Nazca Ridge seems to be a segment boundary
- Northern segment may rupture in one or several earthquakes
- Southern segment may rupture partially (Mw 8.4) or wholly (Mw 8.8)
- Largest known events have not yet recurred in the 20th-21st centuries

(Dorbath et al. 1990; Okal et al. 2006; Pritchard & Fielding 2008)

Central & Southern Peru

1530s:
Spanish
conquest



- Likely remote triggering in 1687 (2 Mw 8+ earthquakes separated by ~24 hours)
- Less likely remote triggering in 1996 (2 Mw 7+ earthquakes separated by 9 months)

(Dorbath et al. 1990; Okal et al. 2006; Pritchard & Fielding 2008)

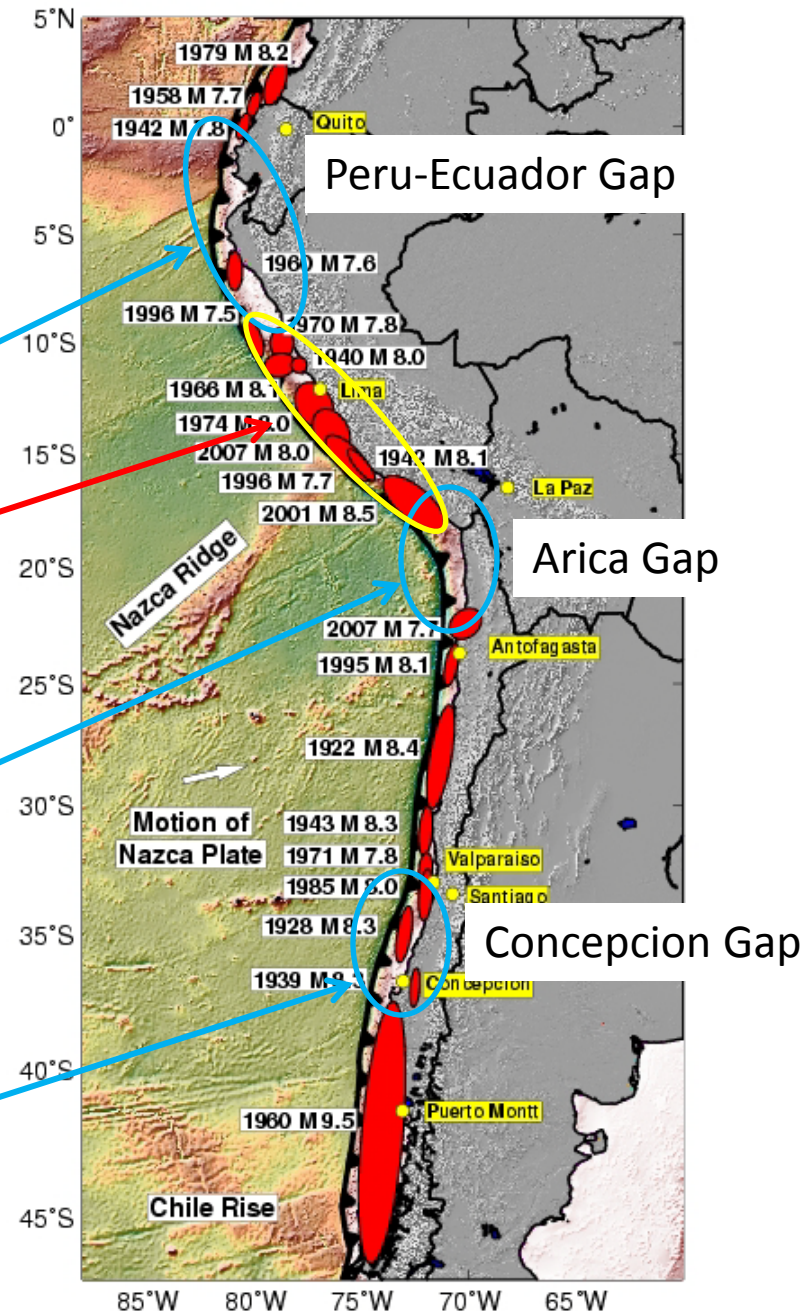
Seismic Gaps

No Mw 8+ historical events;
more complex tectonic environment

Is southern Peru safe??

Previous large EQ 1877 Mw ~9.0

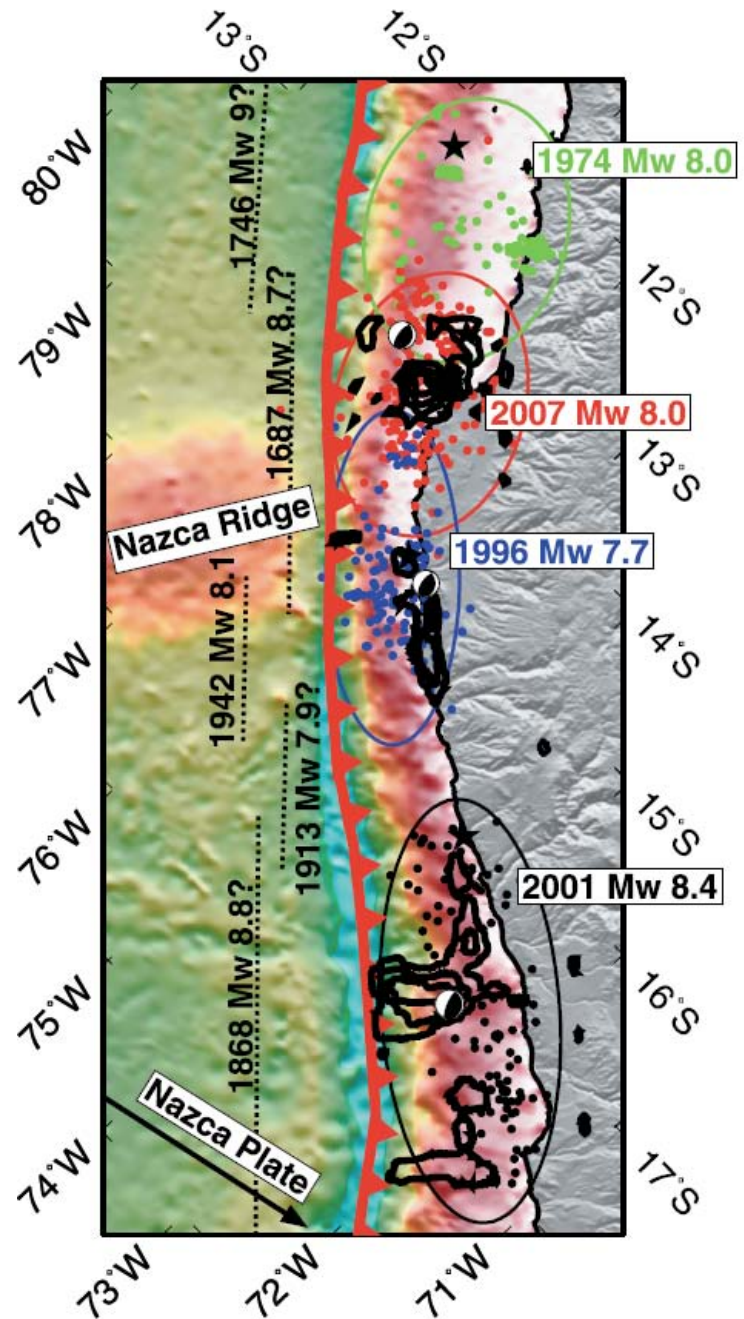
Previous large EQ 1835; at
least partially filled in by
February 2010 Mw 8.8 EQ



(Pritchard 2010)

Seismic Gaps

- Detailed modeling of recent rupture areas based on geodesy suggests that aftershock-based estimates may be too large.
- Future large earthquakes may occur over the Nazca Ridge and/or between the 1996 and 2001 ruptures.
- Southern Peru is unlikely to suffer a Mw 9 earthquake in the near future, but Mw 8 earthquakes are a definite possibility.



(Pritchard & Fielding, 2008)

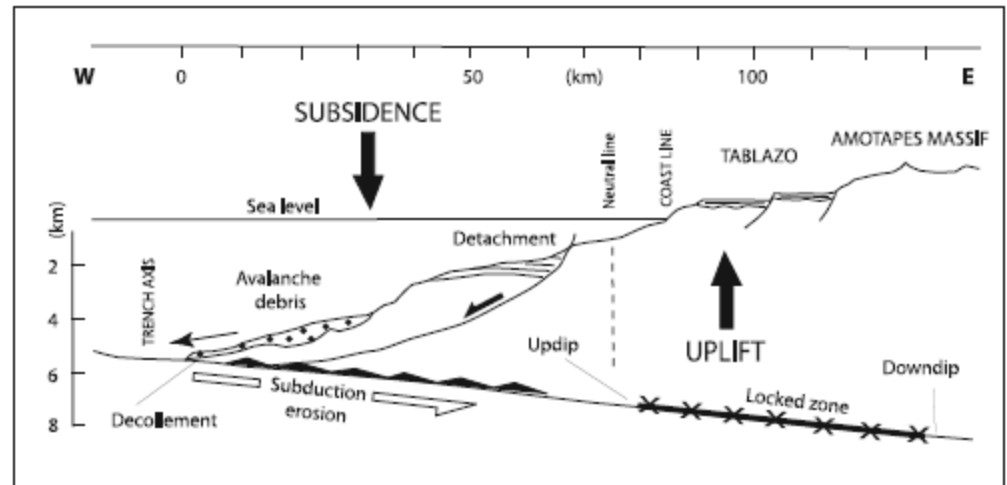
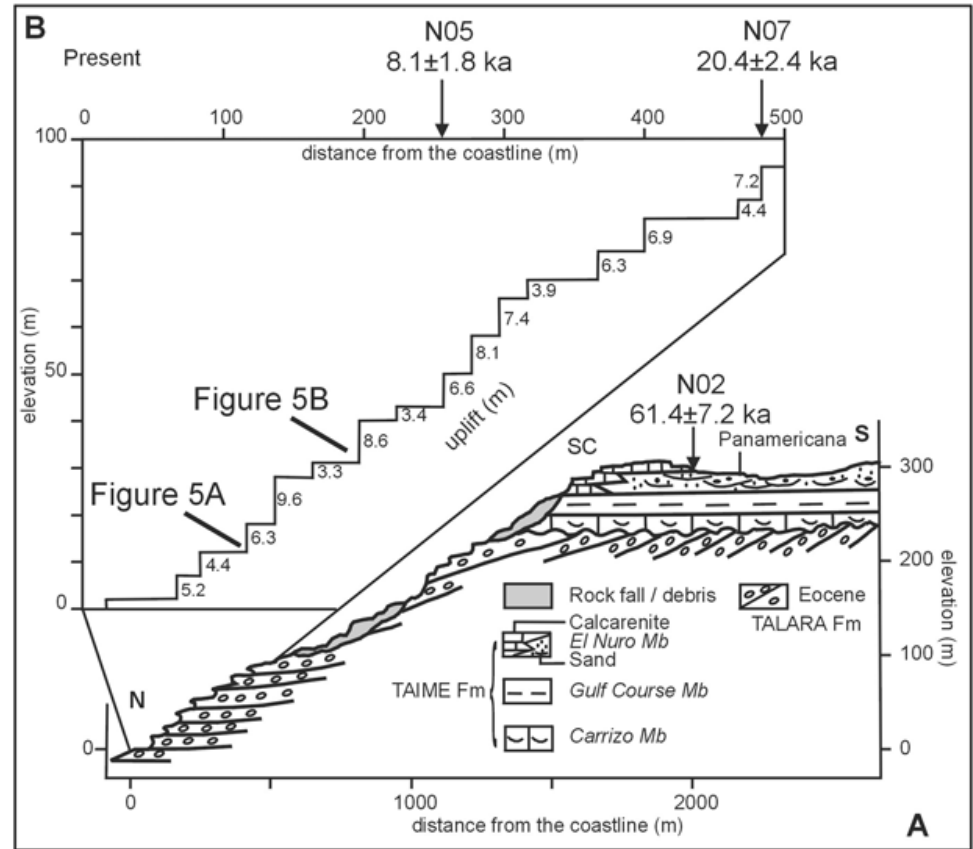
Northern Peru

- Southern & central Peru are a relatively well-behaved subduction zone; northern Peru is comparatively poorly understood.
- 1619 Trujillo earthquake (Mw 7.7-8); unclear if an interplate event (Dorbath et al. 1990)
- 1960 slow “tsunami earthquake” (Mw 7.6); largest recorded event (Pelayo & Wiens 1990)
- Poorly coupled plate interface?

Northern Peru

- Marine terraces suggest that coseismic uplift occurs locally
- Cabo Blanco: 10-12 mm/yr uplift; earthquakes every 1250-1450 years??
- Offshore seismic profiles show normal faults (collapse due to subduction erosion?)

(Bourgeois et al. 2007)



Permanent Deformation

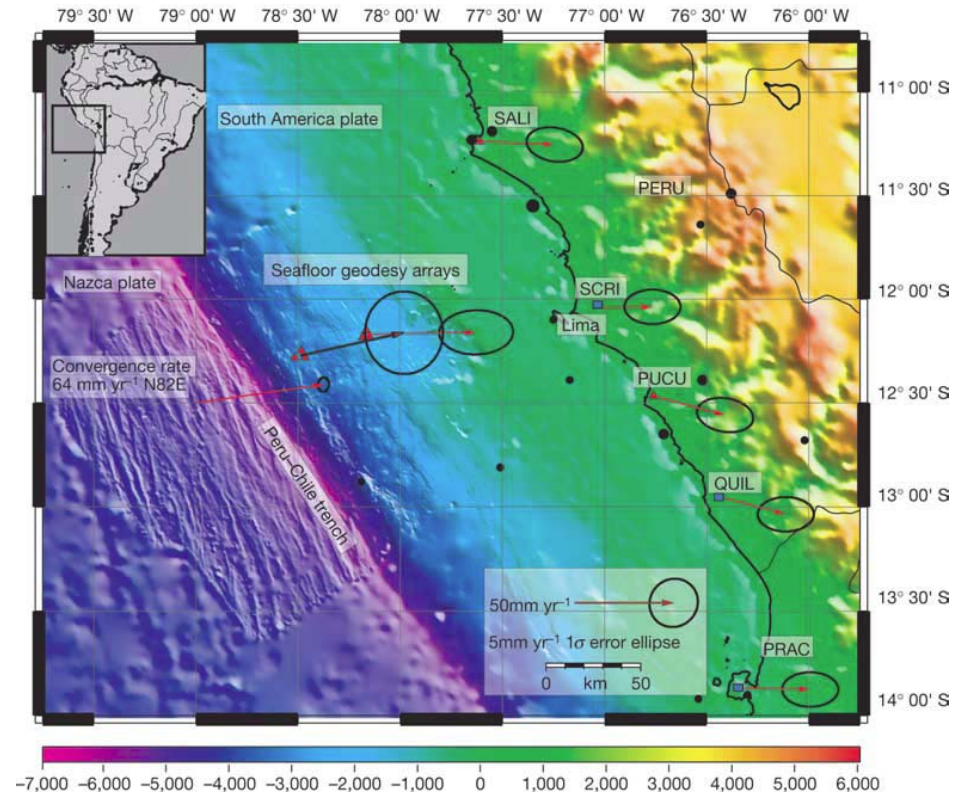
- Marine terraces in northern and southern Peru demonstrate permanent uplift of coastline.
- Mechanisms for this uplift are unclear (distributed deformation, splay faulting, underplating?)
- Also unclear when permanent uplift occurs in relation to the subduction zone seismic cycle (coseismic, post-seismic, interseismic?)



(e.g. Macharé & Ortlieb 1992; Pedoja et al. 2006)

Plate Interface Coupling

- Distribution of large earthquakes along the entire coast of central and southern Peru suggests coupling is generally strong.
- Modeling of seafloor geodesy near Lima suggests that the locked zone in central Peru is between 2 and 40 km depth.
- Shallow locked zone may be responsible for generating large tsunamis.
- Northern Peru subduction interface may be only weakly coupled.

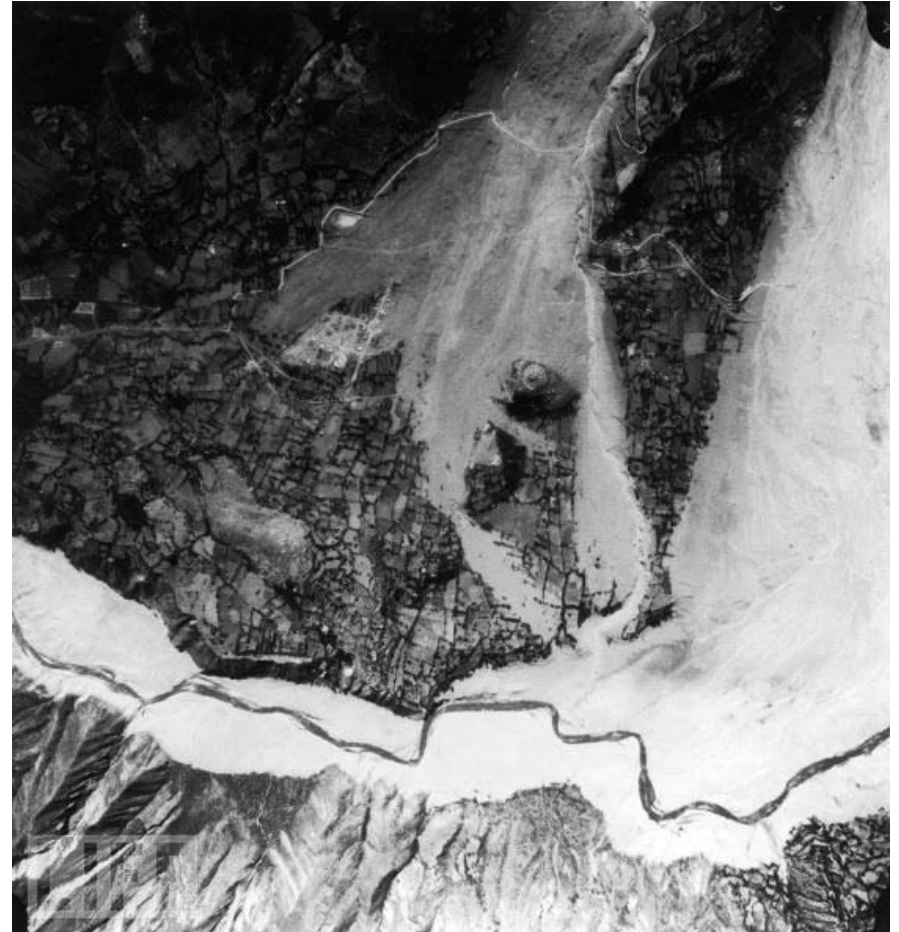


(Gagnon et al. 2005)

Non-Subduction Earthquakes

1970 Great Peru (Chimbote) Earthquake, Mw 7.9

- Possibly due to normal faulting within the subducting Nazca Plate (Abe 1972).
- Deadliest earthquake in Peruvian history with 66,000 fatalities.
- [Huayco](#) (mud avalanches) from the slopes of Nevados Huascarán buried entire towns.
- A very similar earthquake occurred in 1725, in which huayco buried the same towns.



Non-Subduction Earthquakes

- Assorted Mw 6-7.5 inland earthquakes
- Cusco, 1650 – Natives reportedly parade a statue of Jesus to stop an ongoing earthquake; it supposedly works.
- Cusco, 1950 – Mw 6.0 earthquake causes major damage; Jesus paraded again.



El Señor de los Temblores

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