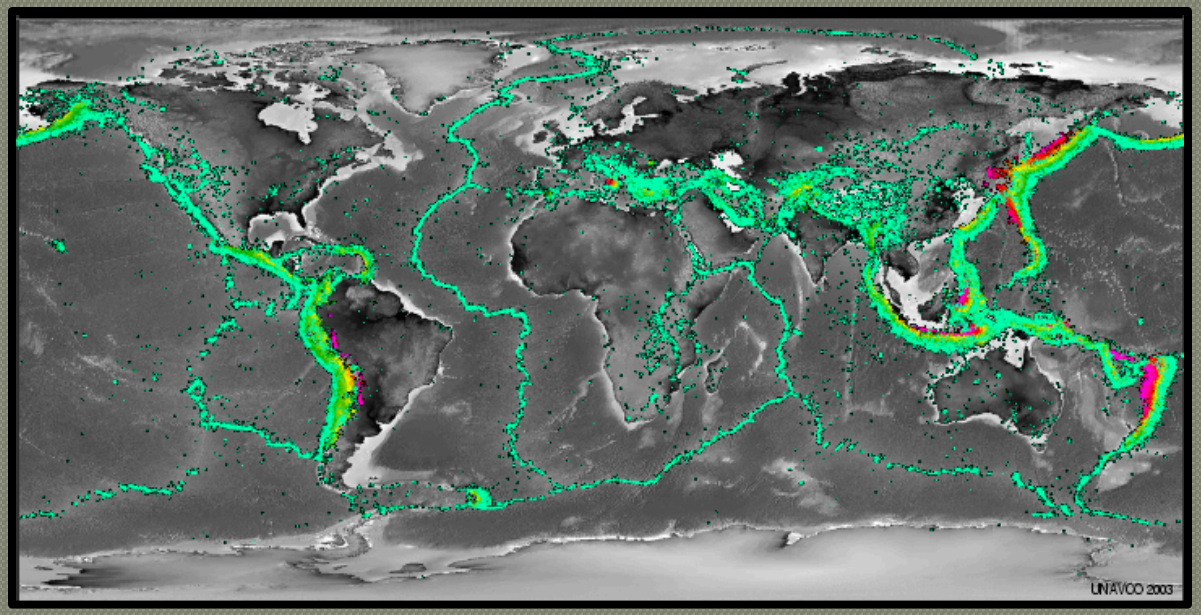
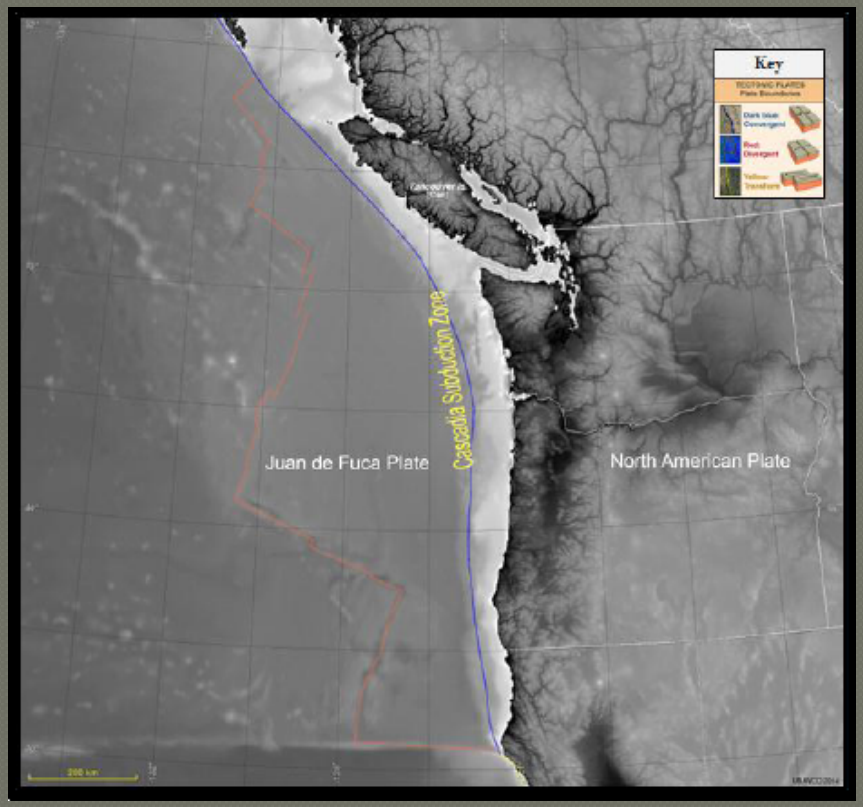
Megathrust Earthquake Controls along the Cascadia Subduction Zone

By Andrew J. Redifer



Source: Jules Verne Voyager

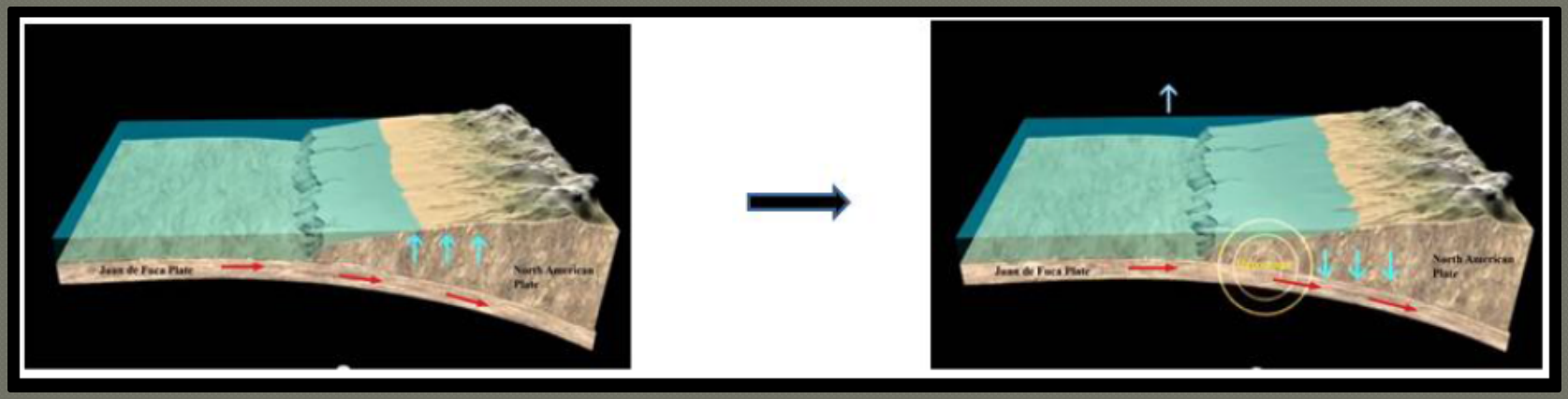
Study Area: Cascadia Subduction Zone



- Geographic Setting:
  - ~1,000 km in length
  - Located off the coast of Southern California to Vancouver Island
- Tectonic Setting:
  - Subduction Zone
  - 60-130 km offshore
  - Juan de Fuca Plate & North American Plate
- Historic Setting:
  - January 26, 1700 [*Goldfinger (2003)*]
  - Evidence of 6 Events in last 2,000 years [*Nelson (2006)*]
  - 12 separate tsunami events over past 5,000 years [*Nelson (2006)*]

Source: Jules Verne Voyager

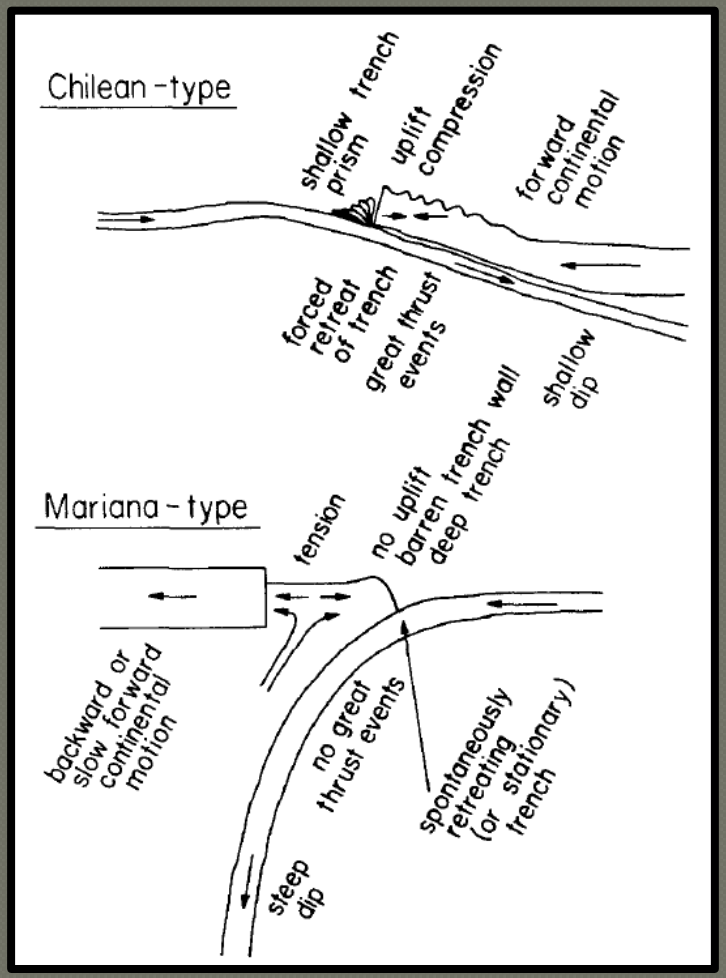
Megathrust Earthquakes



- Left Image:
  - N. American plate flexing upwards due to drag of the underlying plate beneath.
- Right Image:
  - Hypocenter of a Megathrust earthquake.
  - N. American plate moves out to sea due to the removing of the upward flexure.
  - Lowers the coastline causing a rise in sea level

Source: Modified from film: Active Earth Awareness: The Silent Subduction Zone

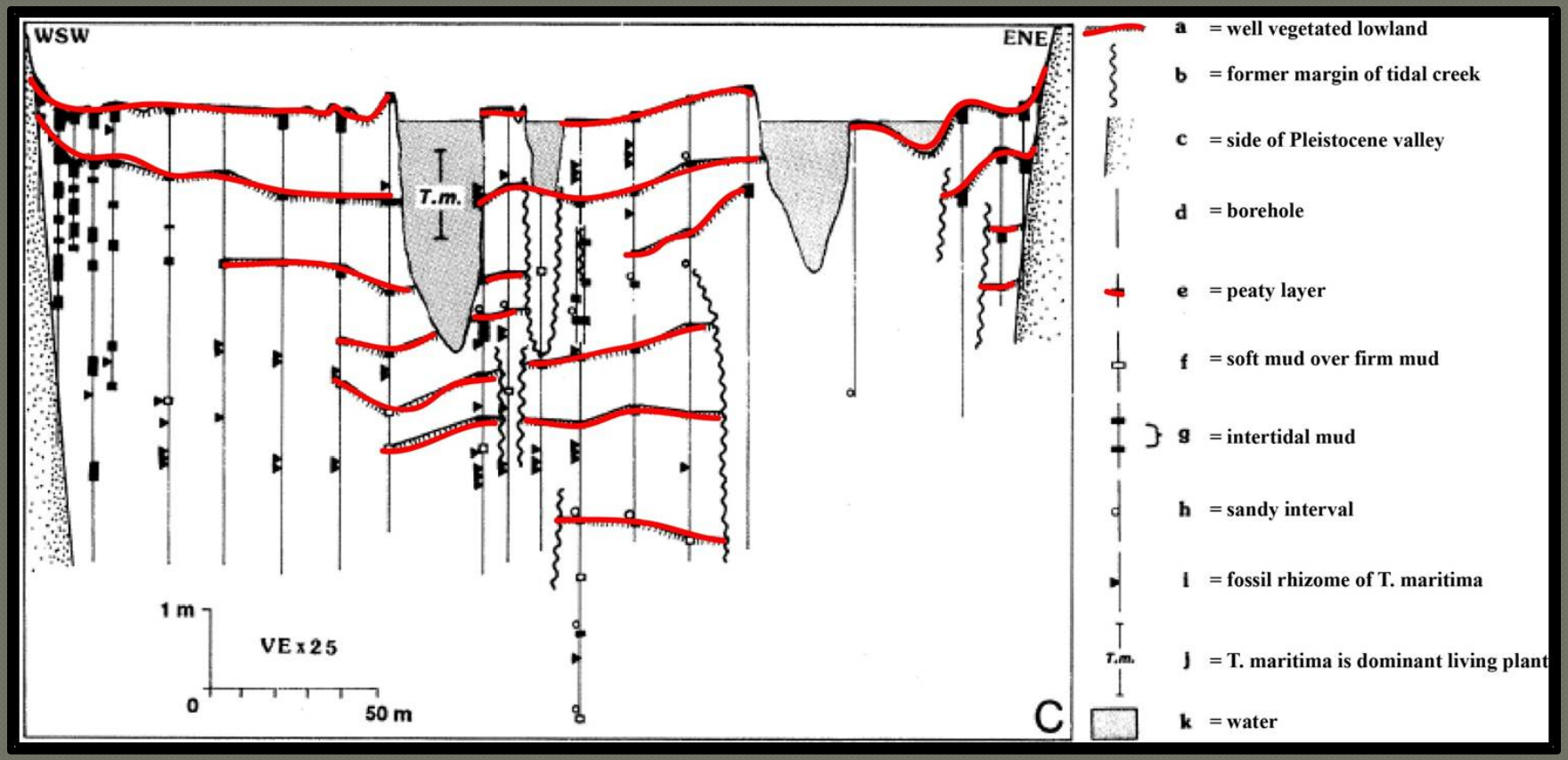
Reclassification of Cascadia



- Chilean-type:
  - Shallow dip
  - Strong coupling b/w plates
- Mariana-type:
  - Steep dip of the down going plate
  - Weak coupling b/w plates

Source: [Uyeda (1979), Heaton & Kanamori (1984)]

Strong Evidence for past Megathrust-type Earthquakes

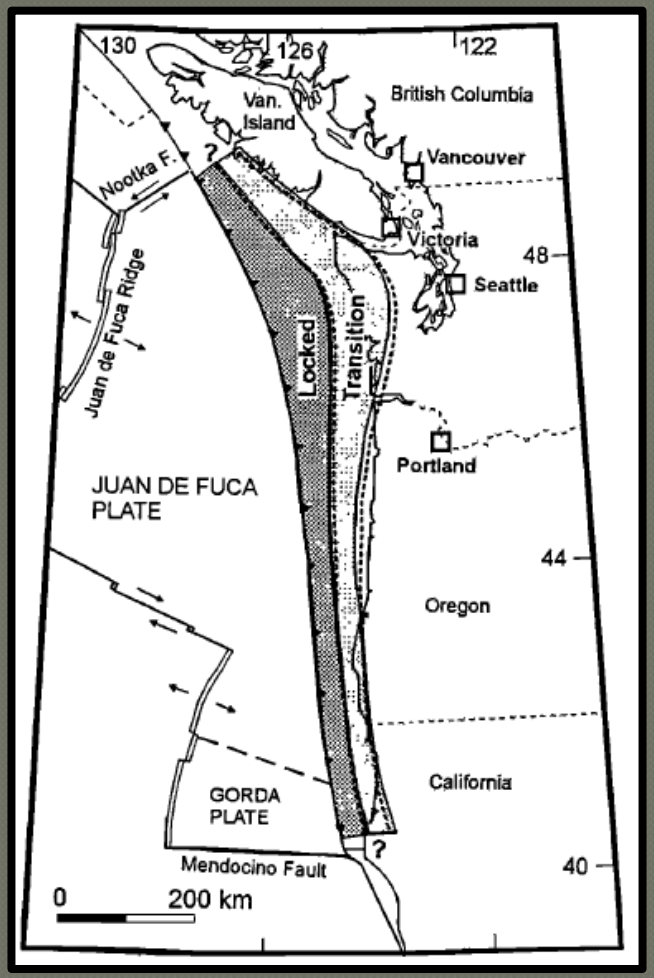


Modified from Atwater (1987)

Research Question

- *What tectonic processes and geometric constraints along the Cascadia subduction zone control megathrust earthquakes?*

Observation: Locked Zones



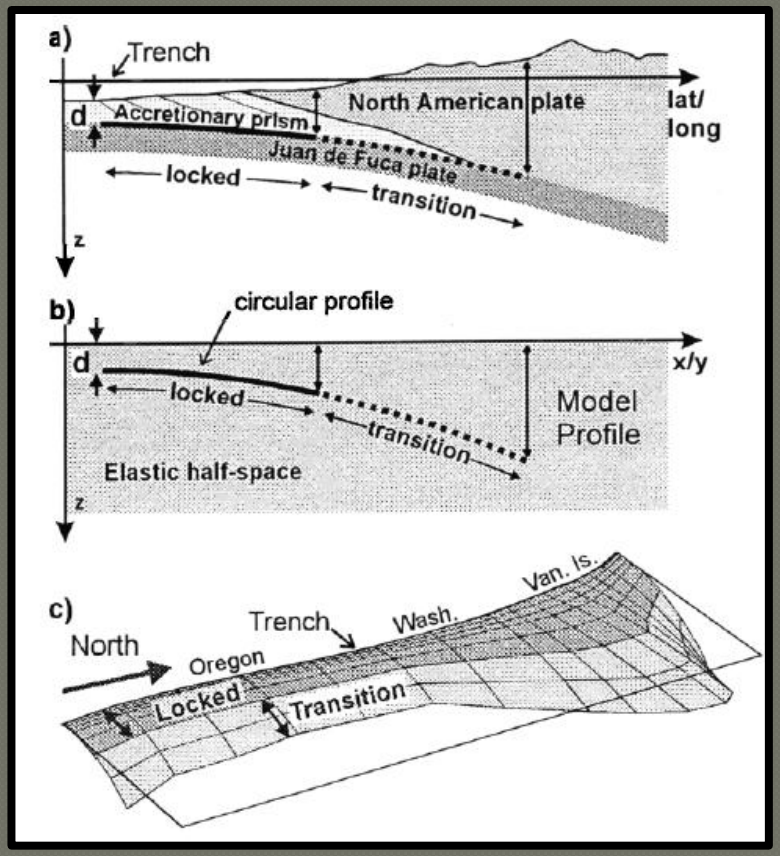
- Methods:
  - Geodetic measurements along the coast
  - N. California to Vancouver Island
- Results:
  - Vertical and Horizontal Deformation
  - Shaded region = Locked Zones

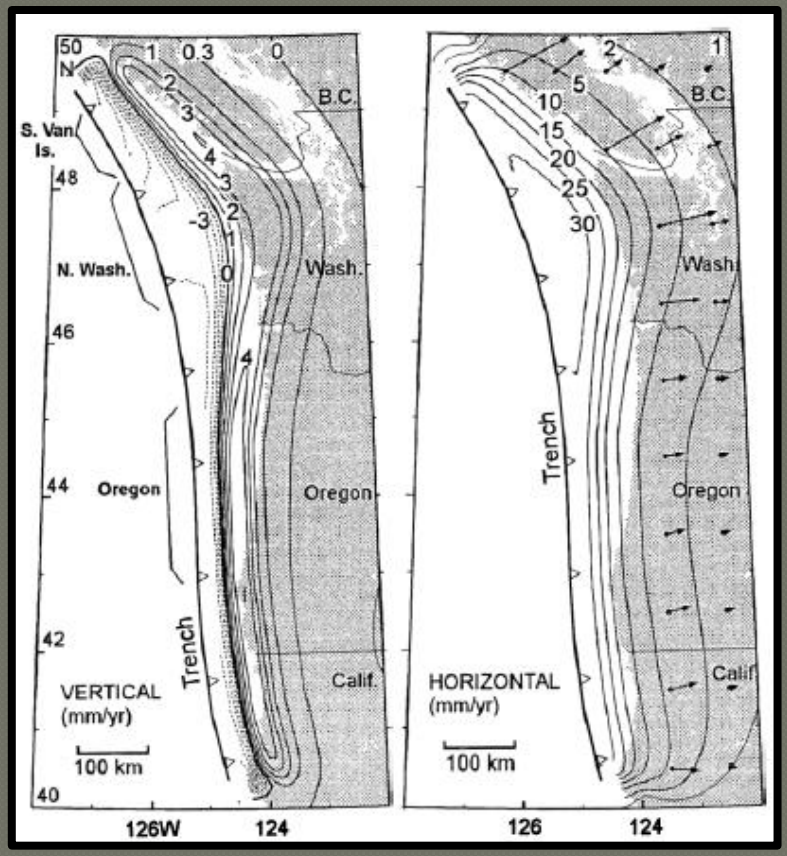
Source: [Fluck (1997)]

Observations: Locked Zone cont.

CROSS SECTIONAL & 3-D VIEW OF CASCADIA

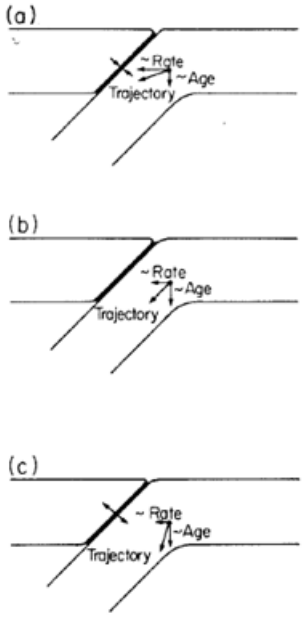
LEFT = RATES OF UPLIFT
RIGHT = DIRECTIONAL VECTORS & CONTOURS OF HORIZONTAL VELOCITY





Source: [Fluck (1997)]

Observations: Preferred Trajectory

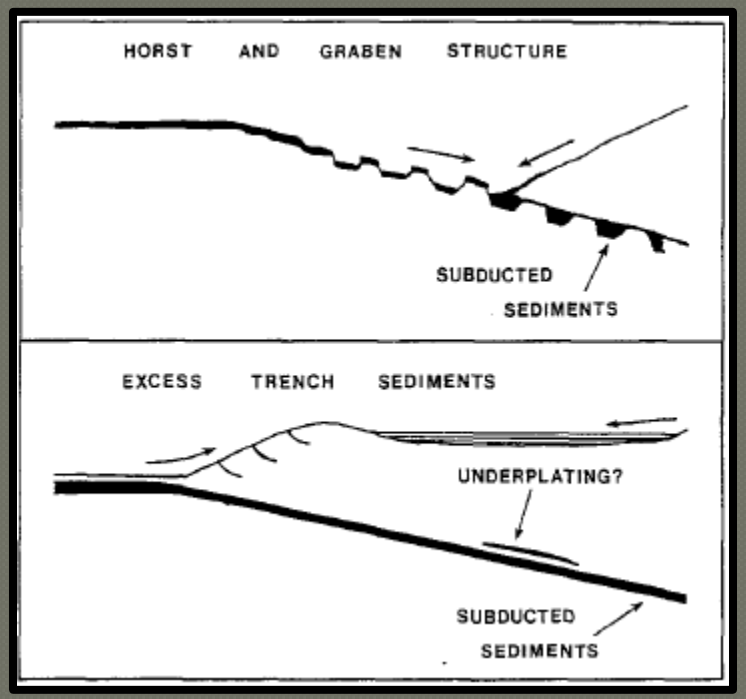


Rate of Convergence	Oceanic Lithosphere Age	Preferred Trajectory
Fast	Young	Horizontal (Largest Earthquakes)
Median	Median	Median
Slow	Old	Vertical (Relatively Aseismic)

- Preferred Trajectory:
  - Angle of descent
- Controls on Earthquake Size:
  - Age of subducting lithosphere
  - Rate of convergence
- Characteristics of Cascadia:
  - Young oceanic lithosphere
  - High rates of convergence

Modified from Ruff & Kanamori (1983)

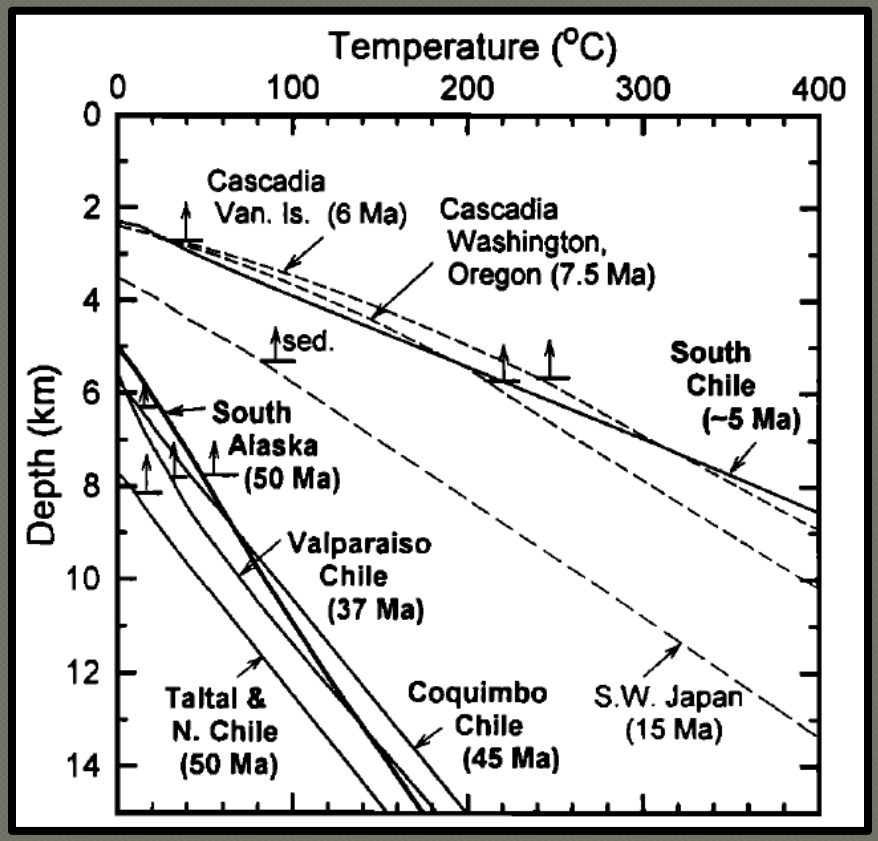
Observations: Excess Trench Sediments (ETS)



- Fate of ETS
  1. Subducted in horst & graben structures
  2. Thin lamination underplates accretionary prism
- Asperities:
  - *Regions of resistance within the subducting lithosphere*
- Two outcomes affecting seismicity b/w plates

Source: [Ruff (1989)]

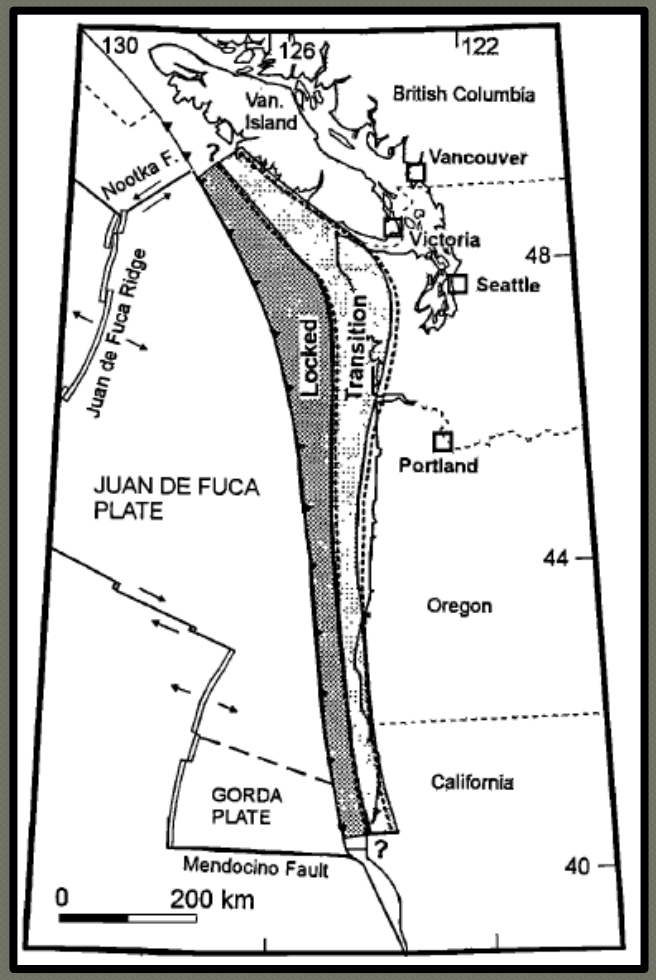
Observations: Temperature vs. Depth of Subducting Plate

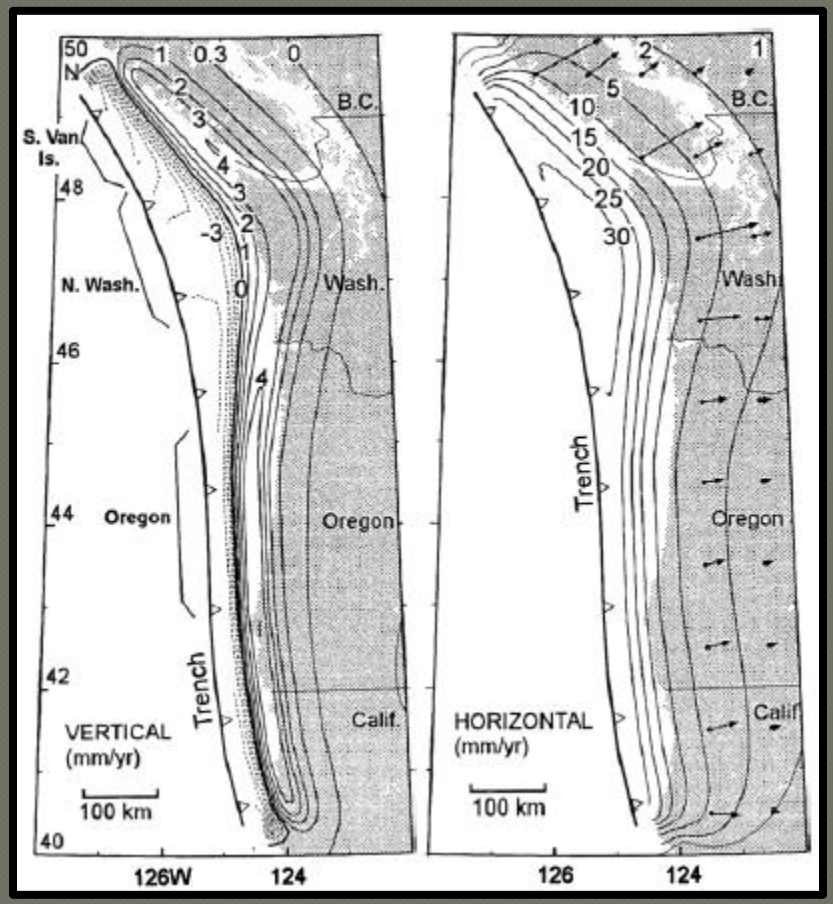


- Cascadia Temperature:
  - Very High
  - 225°C to 260°C
- Explanation:
  - **Note:** horizontal bars = base of ETS
  - High Temp. b/c young oceanic lithosphere & Insulation from ETS

Source: [Oleskevich (1999)]

Observations: Possible Explanation for Confined Southern Locking Zone



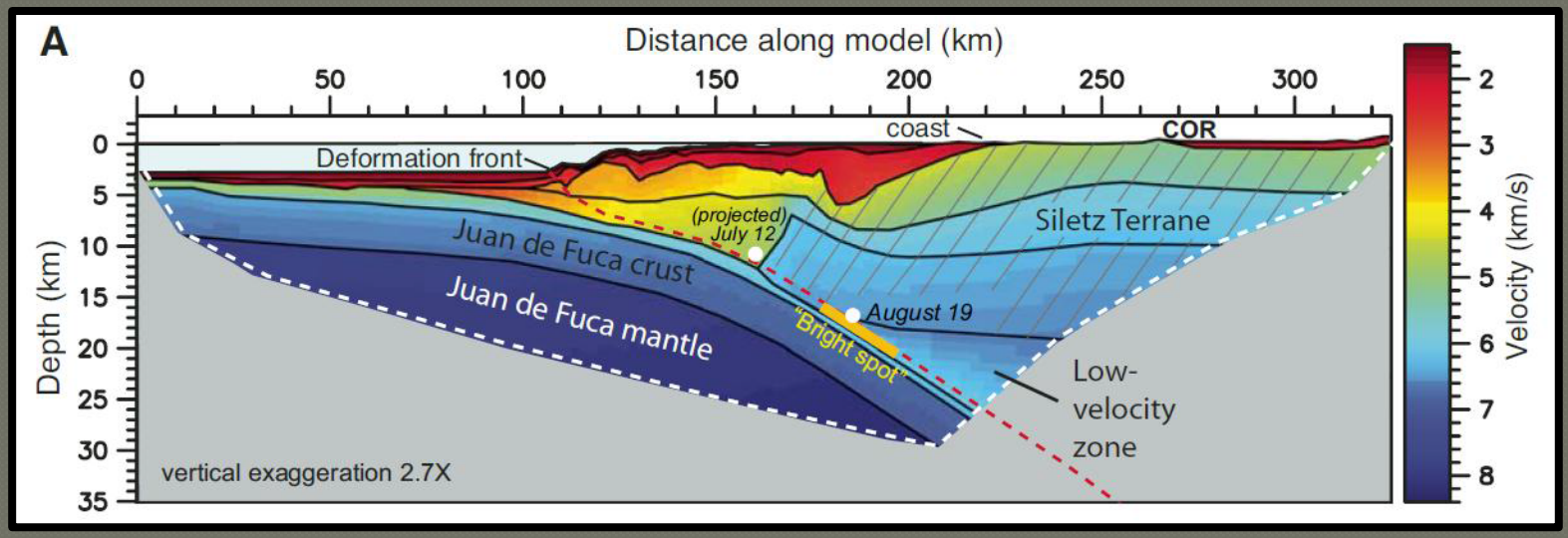


Source: [Fluck (1997), McCaffrey (2000)]

Observations: Episodic Tremor & Slip

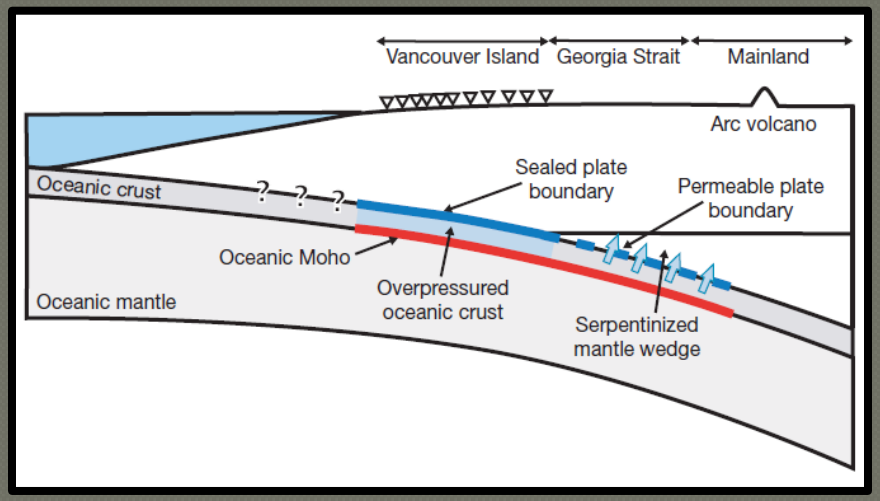
- Episodic Tremor & Slip:
  - *Low frequency long lasting tremors observed at deep depths in subduction zones*
- Implications:
  - Possible recognizable onsets of Megathrust earthquakes [Dragert (2003)]

- Seismic Reflection Model (*strong constraints for plate interface*)
  - Observations of 2004 Central forearc earthquakes recorded at episodic tremor and slip depths
  - Proposed depth of locked or transitional zone



Source: [Tréhu (2008)]

Observations: Decoupling of the Plates



- Proposed Process:
  - Crustal eclogitization
  - Mantle serpentinization
- Possible Detection of this "hydro fracturing of the seal":
  - Episodic tremor & slip

Source: [Audet (2009)]

Conclusions

- Evidence for past megathrust earthquakes along Cascadia:
  - Paleo-tsunami sediments, turbidites and even historic recordings
- Cascadia will continue producing megathrust earthquakes:
  1. High rates of convergence
  2. Young oceanic lithosphere
  3. Nearly horizontal preferred trajectory (large coupling)
- Basin and Range is confining the southern locking zone
- Both young oceanic lithosphere and ETS result in anomalously hot oceanic lithosphere being subducted.
- Possible slip due to subducted asperities could lead to megathrust earthquakes.
- Decoupling is likely a result of a phase change and dewatering of the down going slab

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