Landward Limit Cascadia Great Earthquake Rupture
A summary of constraints

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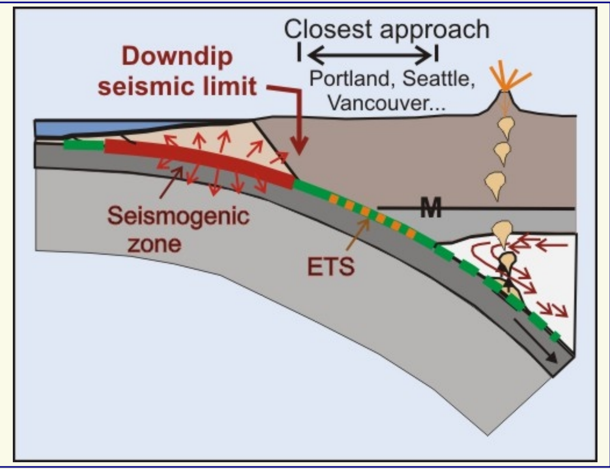
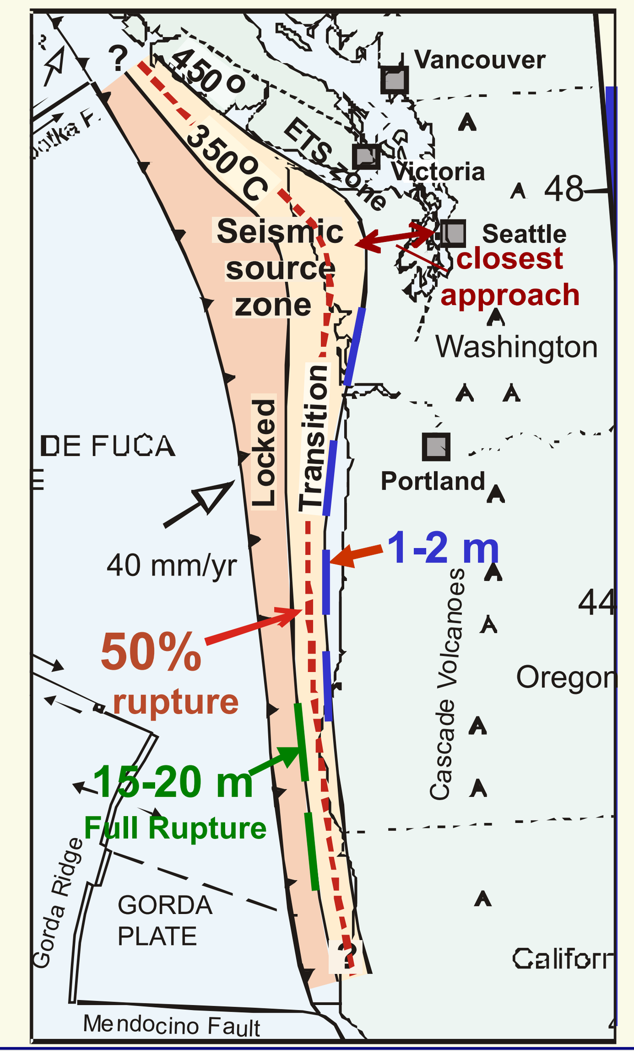
The Landward Limit of Cascadia Great Earthquake Rupture; the most important control of coastal shaking

Note: **actually need ground motion models
Limit references used here: (a) rupture 50% of maximum, i.e., mid-transition (b) and 10-20 % of max., enough for strong shaking
Estimating downdip rupture extent
a) Constraints to past rupture; b) Constraints to the 'locked zone'
c) Seismic physical process/state controls. No constraints are to the actual rupture zone; all require assumptions





Estimating downdip rupture extent:

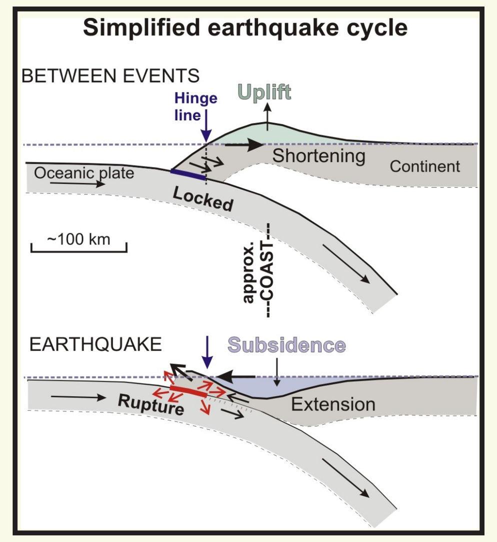
(1) Rupture zone from paleoseismic coastal marsh subsidence (and 1700 tsunami); 'paleo-geodesy'
(2) Locked/transition zones from geodetic deformation & dislocation models: GPS, rep. levelling, tide gauges, abs. grav., etc
(3) Seismic-aseismic behaviour limits from downdip temperatures; "brittle-ductile transition"; 350C full rupture; 450C transition
(4) Change in thrust seismic reflection character from thin sharp (seismic) to thick shear zone (ductile)
(5) Geological associations with rupture, basins just offshore etc.
(6) Landward limit of small thrust and slab earthquakes
The following two appear not to define downdip limit
(7) Forearc mantle corner (aseismic serpentinite & talc on thrust)
(8) Updip limit of ETS slow slip; slow slip accommodates most of plate convergence in ETS zone

For comparisons, choose 50% of maximum rupture, ~10 m; i.e., mid-transition
Smaller rupture, 1-2 m, near landward limit may be important for damaging shaking frequencies

Deformation through great earthquake cycle

Landward limit of full rupture or locked zone approx. over hinge line of uplift or subsidence

Coastal coseismic subsidence requires main rupture seaward of coast except near Mendocino

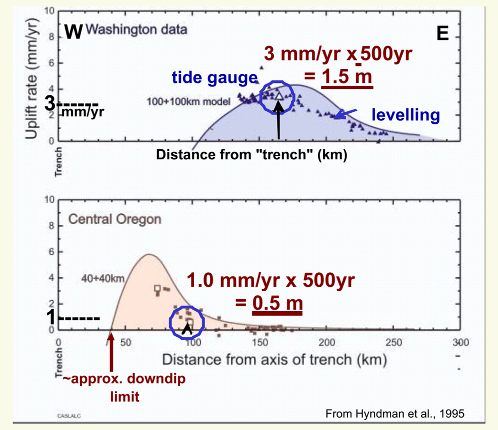


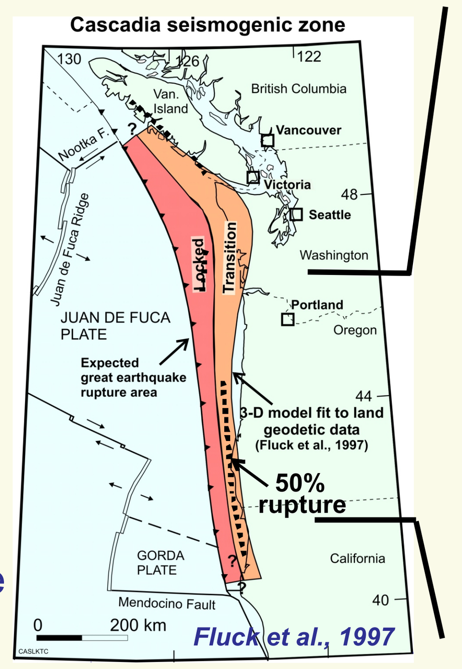
Strain buildup & rupture release

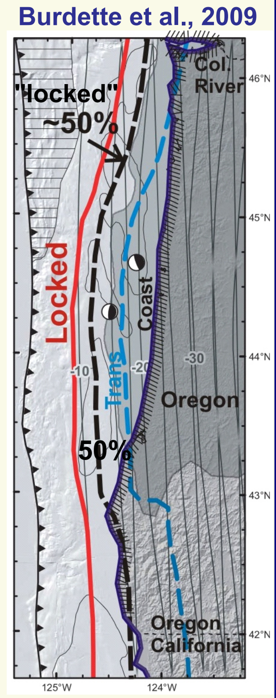
2. Geodetic limit: Repeated levelling and tide gauge data

Coastal coseismic subsidence approx. equals current uplift rate/yr x 500 yr seism. interval
(but post-seismic transients are important)

Mitchell et al., 1994; Hyndman and Wang, 1995; Verdonck, 2005
Updated Oregon data by Burdette et al., 2009



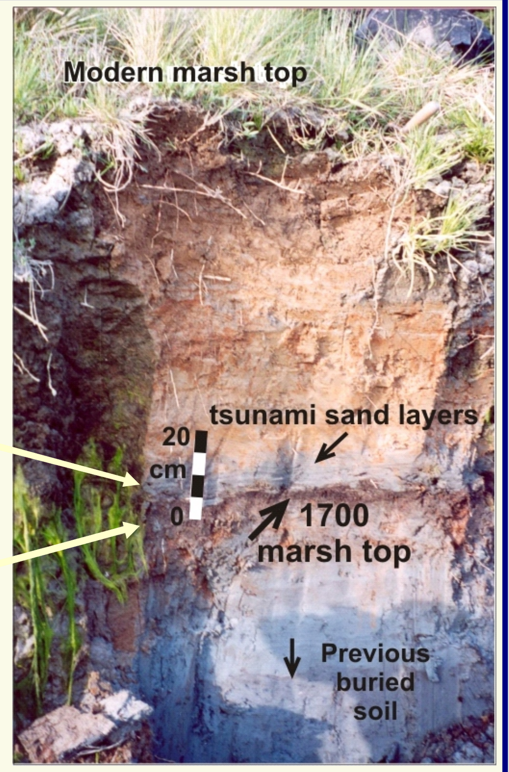




~50% "locked" near coast N. Wash.; ~50 km offshore N. Oregon

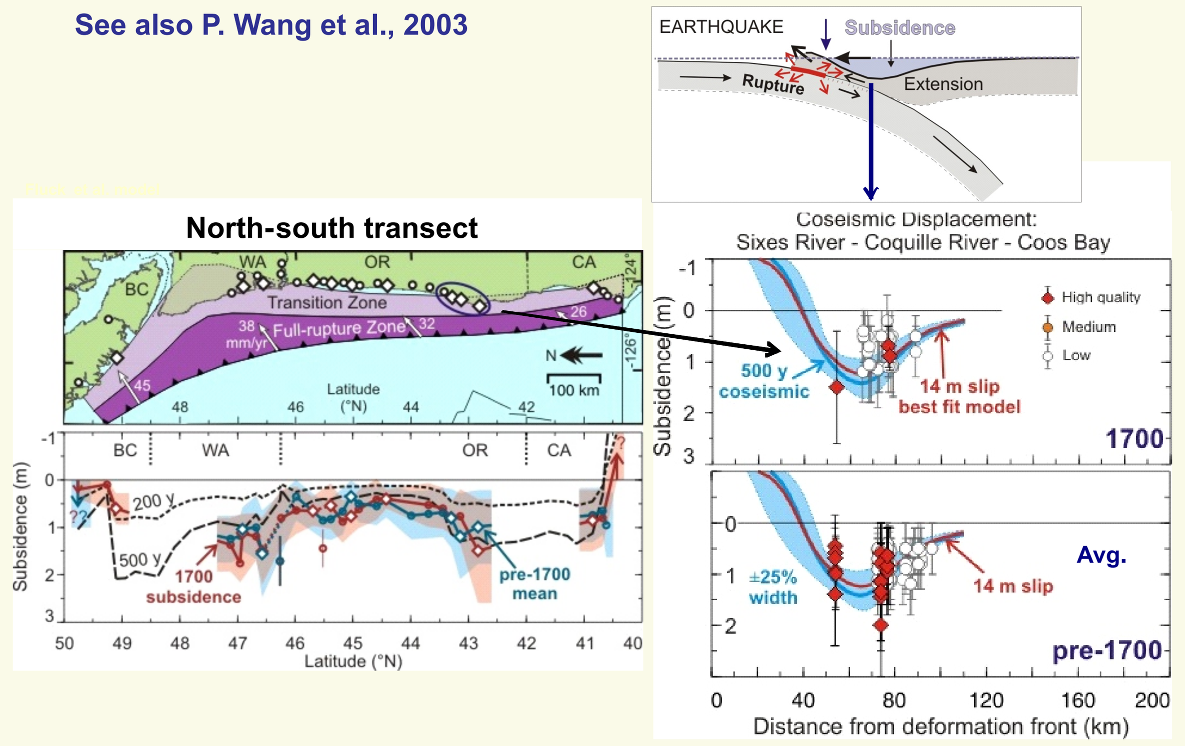
1. Coastal marsh subsidence for 1700 and earlier events

Coseismic subsidence:
Sea-level marker organisms in sediment above and below old marsh top

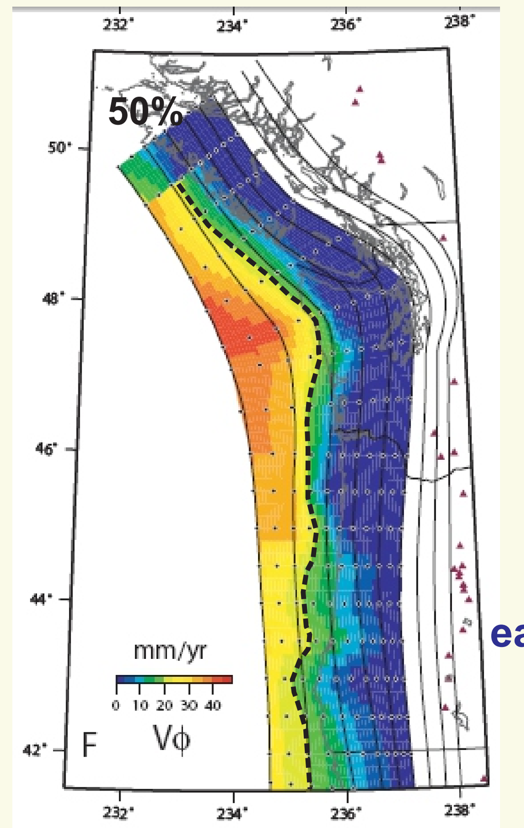


Coastal marsh subsidence for 1700 and earlier megathrust earthquakes *(Leonard et al., 2010)*

See also P. Wang et al., 2003

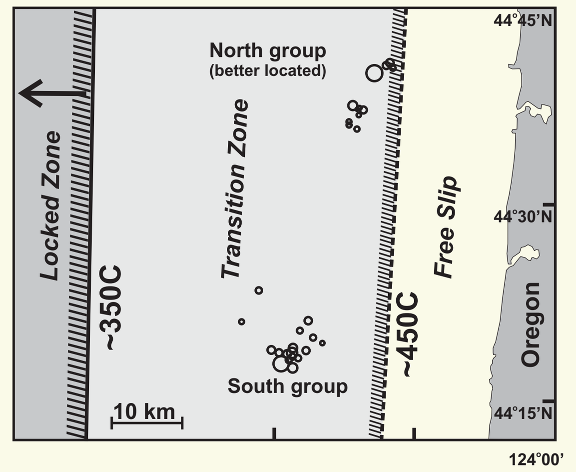


Dislocation model inversions of GPS data ~50% plate rate

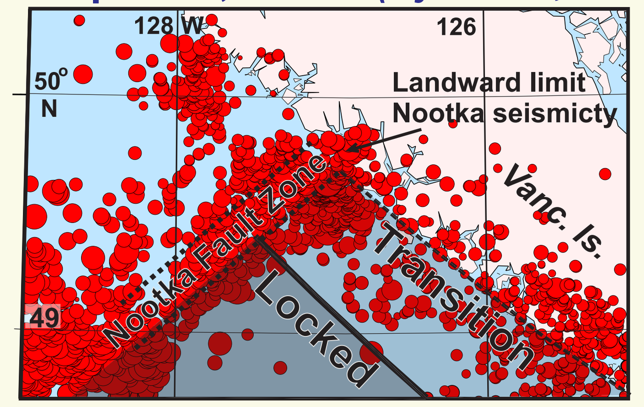


McCaffrey et al., 2007
(smoothing 0.6)

Landward limit of small earthquakes on subd. thrust off Oregon *(Trehu et al.)* compared to locked and transition zones; mafic seamounts, eqs. to 450C?

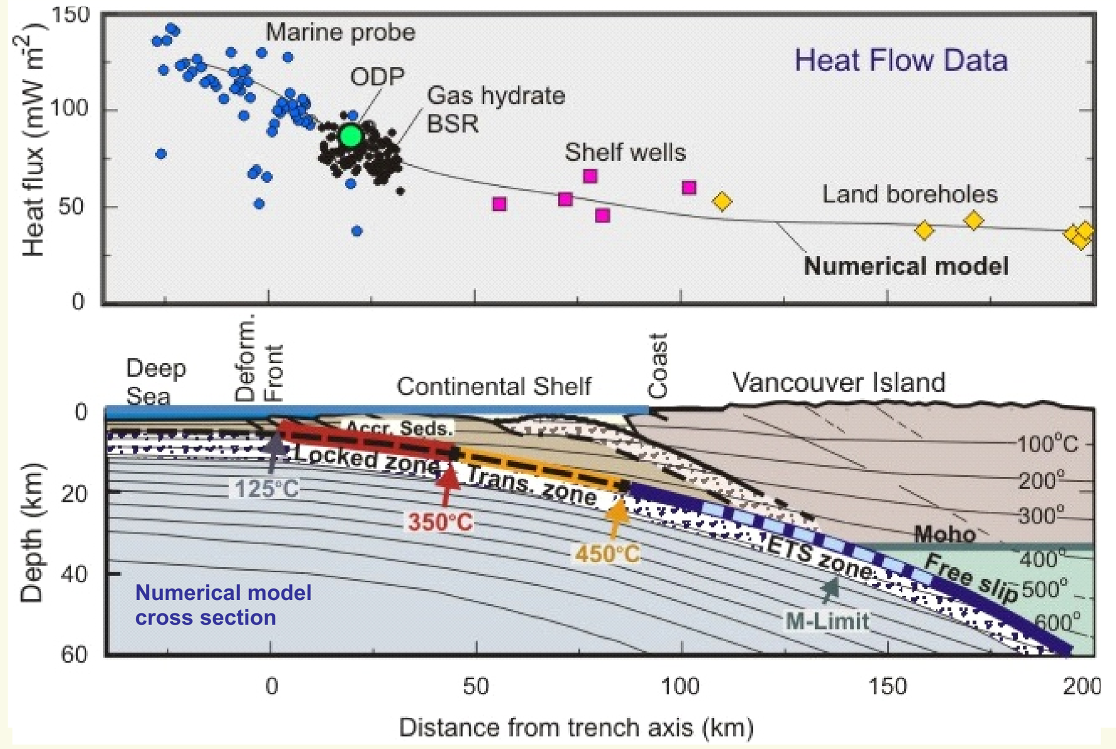


Landward limit of Nootka Fault earthquakes, ~450C *(Hyndman, 2013)*



3. Thermal limit for rupture extent:

Numerical thermal model seis. and trans. zones to 350 & 450°C from lab data



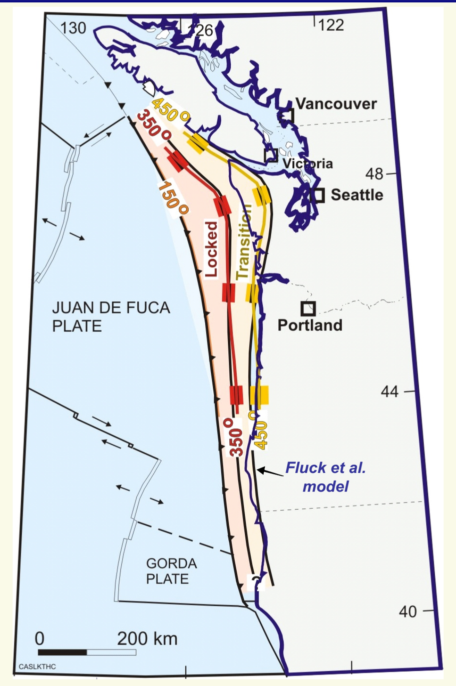
3. Thermal Limit

2D thermal model profiles

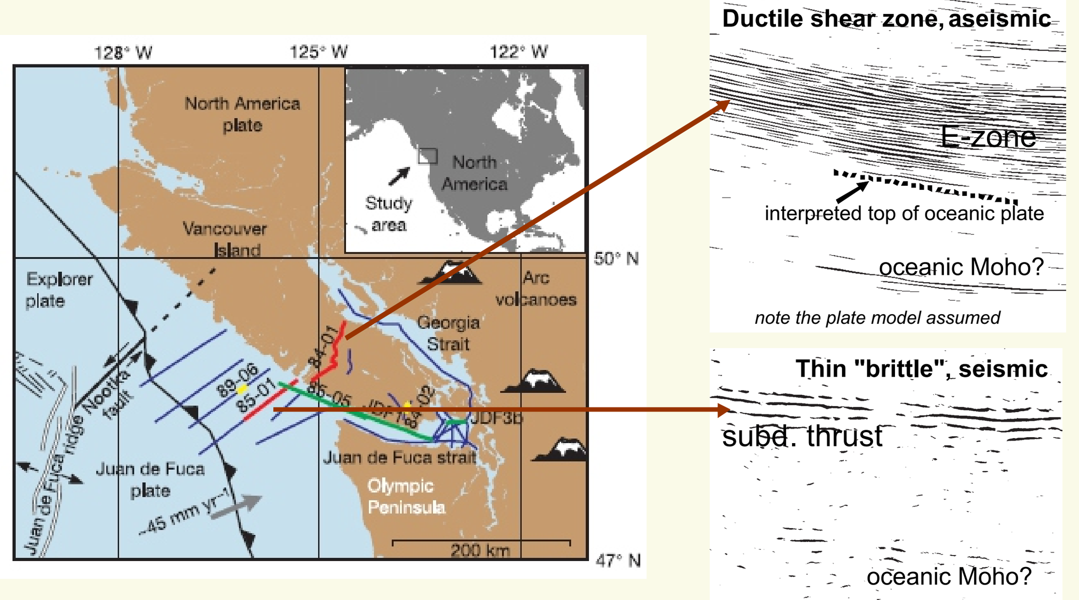
Thermal limit for downdip rupture extent: seismic to 350°; transition to 450°
(50% 'rupture' estimate is mid-transition)

Estimates seismic behaviour to be limited to mainly offshore

Hyndman & Wang, 1995; Oleskevich et al., 1997
McKenna & Blackwell, 2002; Currie et al., 2004;
Cozzens & Spinelli, 2010



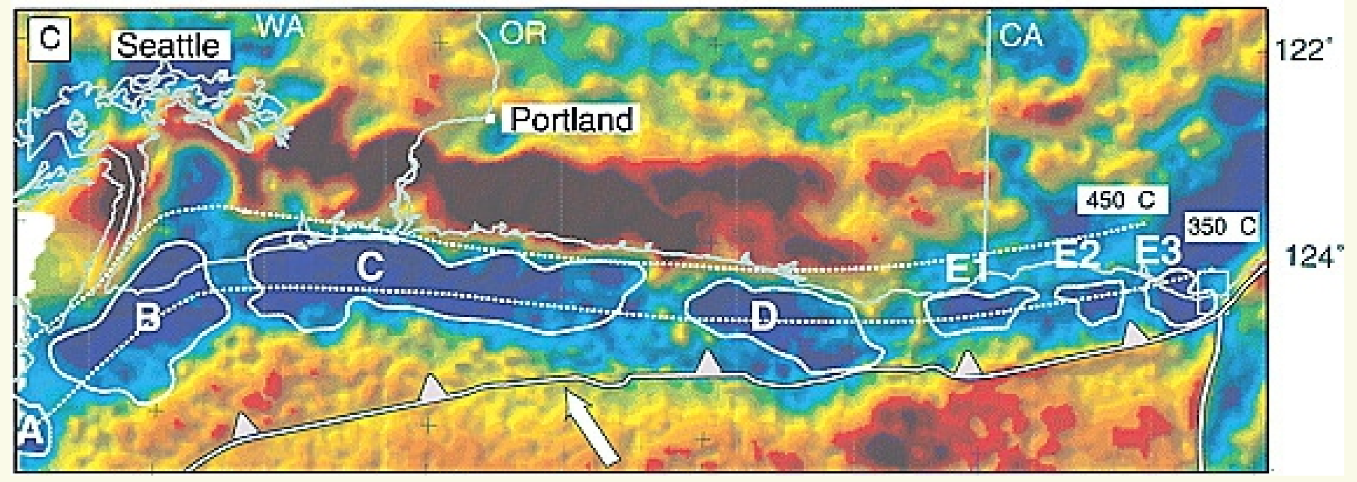
4. Change in thrust reflection character *(Nedimovic et al., 2003)*
From thin sharp (seismic) to thick shear zone (Ductile)



Just west of Van. Is. coast. *Note question of 'E' zone and location of top of plate.*

6. Rupture area may be defined by marginal basins

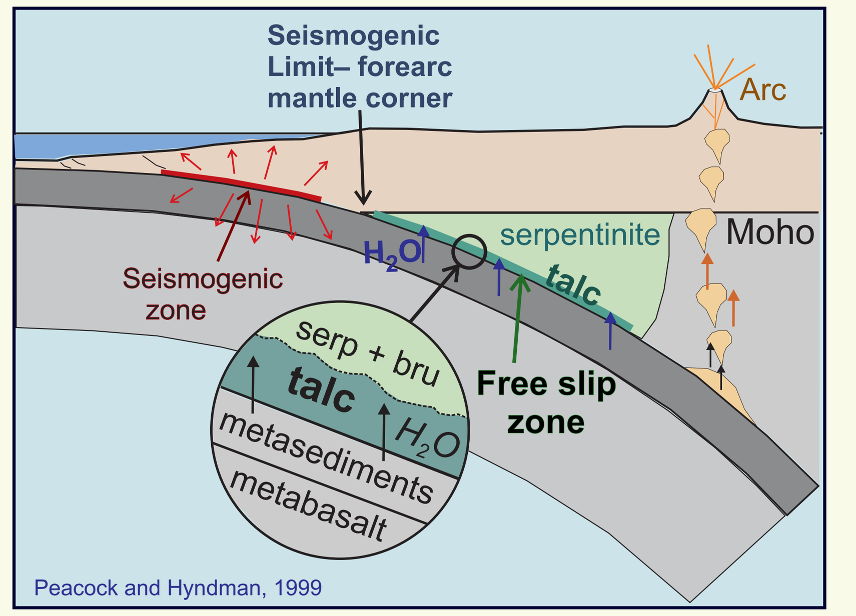
as defined by gravity etc.; also may define event segmentation (e.g., Wells et al., 2003; Fuller et al., 2008; Morgan et al., 2008)



5. Forearc mantle corner

(Hyndman et al., 1997; Peacock and Hyndman, 1999)

Downdip of forearc mantle corner there is aseismic serpentinite and talc overlying the subducting crust. This limit fits many (cold) subduction zones (Hyndman et al., 1997) and several recent megathrusts. *Cascadia is likely thermally limited further seaward. This may be a firm limit for 1-2 m displacement.* Forearc mantle corner is just inland of coast *(P. McCrory, 2012).*

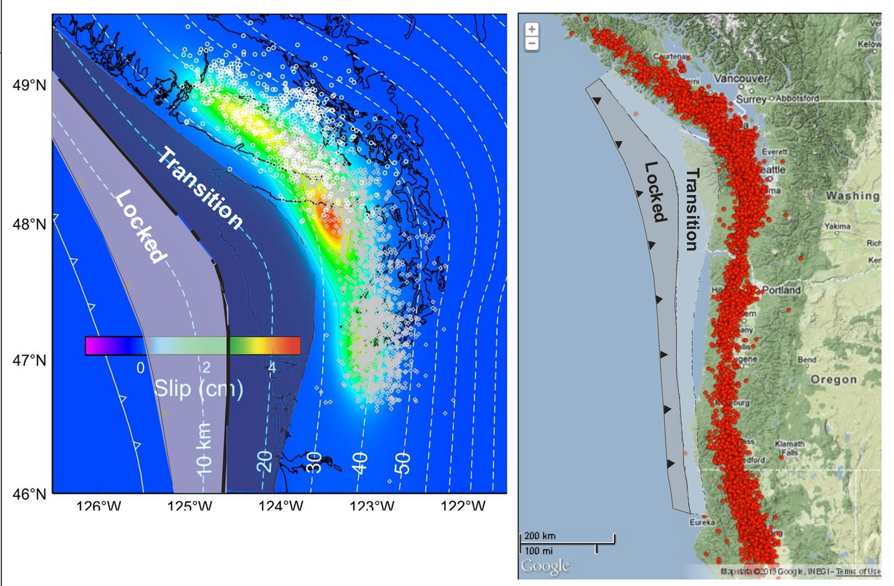


7. Updip limit of ETS slow slip

(K. Wang, slip contours)

~50 km between slow slip 50% and 50% rupture estimates.
Cascadia likely thermally limited further seaward.

In ETS zone most of plate convergence accommodated by slow slip, so little elastic strain for future rupture



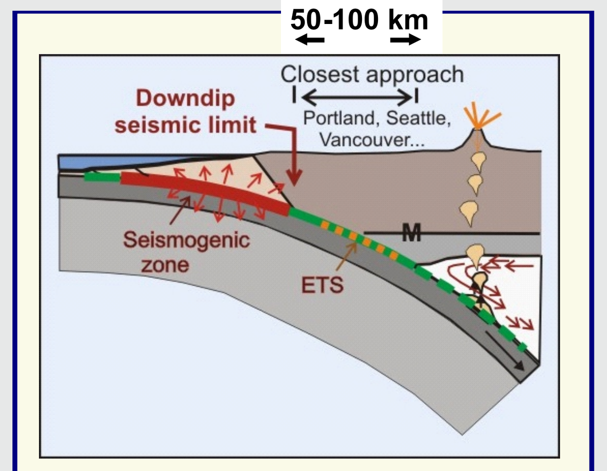
Tremor: H. Kao and A. Wech

Summary

(1) Main rupture zone from paleoseismic coastal subsidence 1700 and earlier: few 10's km seaward of coast (except southernmost Cascadia)
(2) Locked/transition zones from geodetic deformation, GPS, leveling, etc.: few 10's km seaward of coast (near coast N. Wash. and landward N. Calif.)
(3) Seismic behaviour temperatures (350C full rupture 450C transition zone): mid transition just seaward of coast (just landward N. Washington and N. Calif.)
(4) Change in thrust seismic reflection character: just seaward of coast for S. Vancouver Island example
(5)Geological associations with rupture, basins: just offshore
(6) Landward limit small thrust events & Nootka events: just seaward of coast
The following two appear not to define the downdip limit
(7) Forearc mantle corner (aseismic serpentinite & talc on thrust)
(8)*ETS slow slip updip limit and forearc mantle corner: landward of the coast, but actual rupture 50% limit ~50 km further seaward from other constraints

Other factors and issues

(1) Appropriate landward limit for estimating significant ground motion? What is "significant rupture displacement" for ground motion?
(2) Relation between geodetically estimated "locked/transition" zones and downdip coseismic displacement (that produces significant ground motion)?
(3) Relation between the coastal marsh subsidence i.e., months to years, (including afterslip and relaxation) and fault coseismic displacement
(4) Relation between updip limit of ETS slow slip and tremor, forearc mantle corner, and downdip limit of important coseismic displacement? Or offset of 50 km?
(5) Important path effects to the inland cities, i.e., reflection off oceanic Moho, the serpentinized forearc mantle, etc.
(6) Comparisons with recent great earthquakes elsewhere; testing of methods



Current estimates
Downdip rupture limit:
~50% is near coast,
50-100 km from major cities.
10-20% of full rupture is just inland of the coast.