

The Aleutian-Alaska Subduction Zone Is Prone to Rupture in Great and Giant Megathrust Earthquakes—Why Is this So, and How Can Scientific Information Mitigate Consequences?

David W. Scholl

University of Alaska Fairbanks and USGS Emeritus, Menlo Park, CA

Roland von Huene, USGS, Emeritus, Menlo Park, CA

and

Stephen H. Kirby, USGS, Menlo Park, CA

Note: AGS meetings will be at the BP Energy Center for 2010-2011.

Please check the website (www.alaskageology.org) and issues of the AGS newsletter for updates.

This newsletter promotes the September luncheon talk of the Alaska Geological Society, to be held Thursday, September 16th, at the BP Energy Center.

THE FIELD SETTINGS OF LARGE SUBDUCTION ZONE EARTHQUAKES

Great (Mw8.0 and larger) and giant (Mw8.5 and larger) megathrust earthquakes occur repeatedly along certain subduction zones and virtually never at others. Why this circumstance should exist has long been the focus of study, wonderment, and debate. But, based on observational information, it seems clear that the nucleation sites and hallmark lengthy, trench-parallel ruptures of great and giant megathrust earthquakes are significantly influenced by physical field relations and settings. The most important of these are:

A) For the underthrusting ocean plate:

- 1) Subducted high bathymetric relief, in particular ridges, fracture zones, and large seamounts, and seafloor roughness generally, and
- 2) Subducted thick sequences (>1-2 km) of trench sediment, and

B) For the upper plate of the forearc:

- 1) Forearc structural highs, and
- 2) Large, structurally deep forearc basins

Great and giant megathrust earthquakes characteristically nucleate below a forearc structural high, or atop a subducted ridge or large seamount, and rupture laterally away for distances of 300-1200 km.

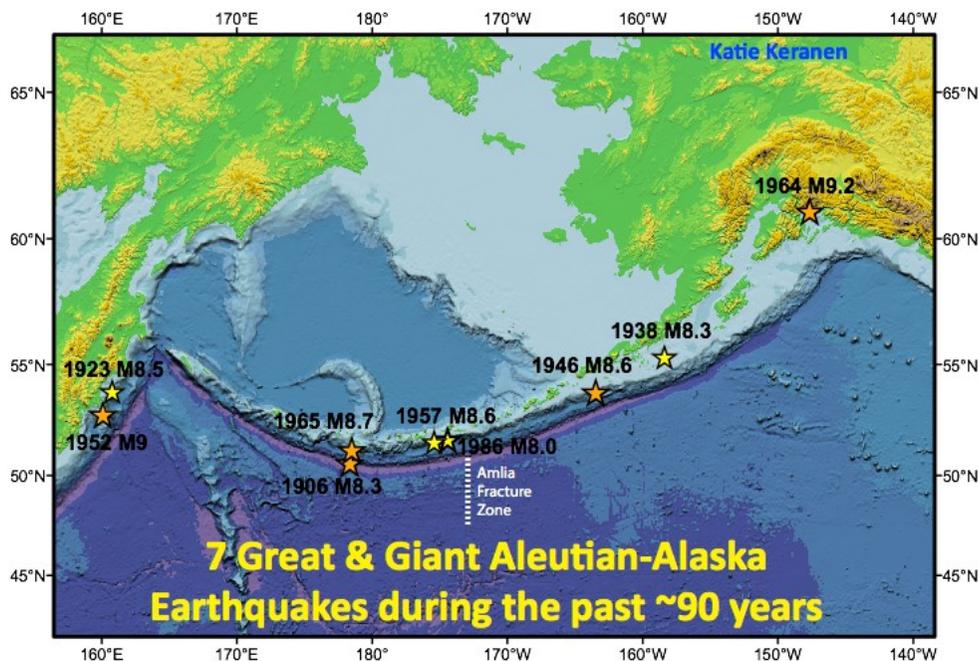
Rupturing commonly terminates at a subducted ridge, fracture zone, or large seamount. As the table below shows for the best-documented instrumentally and geologically recorded great and giant events (19 total), trench sectors with laterally continuous axial deposits thicker than 1.0 km are associated with the occurrence of:

- 53 % of Mw8.0 and larger megathrust earthquakes (10 of 19)
- 67 % of Mw8.3 and larger megathrust earthquakes (6 of 9)
- 75 % of Mw8.5 and larger megathrust earthquakes (6 of 8)
- 80 % of Mw9.0 and larger megathrust earthquakes (4 of 5)
- 100 % of Mw larger than 9.0 (3 of 3).

The reason for this relation, as hypothesized by Ruff (1989), is that subduction of a thick section of trench-floor sediment inserts a laterally homogenous layer of material into the subduction channel separating the lower plate of the underthrusting oceanic crust from the upper plate of the forearc. The interplate surface of the rupturing seismogenic zone probably runs along the top of the subduction channel. The sediment-charged subduction channel mechanically smoothes the roughness of subducted sea-floor relief, allowing ruptures to bypass these barriers (asperities of strong coupling). During a megathrust earthquake, an even, lateral distribution of interplate strength or coupling favors lengthy trench-parallel, strain-releasing ruptures. It is conjectured that smoothing can also be effected by processes of basal subduction erosion that mechanically transfers forearc crustal debris into the strength-evening subduction channel.

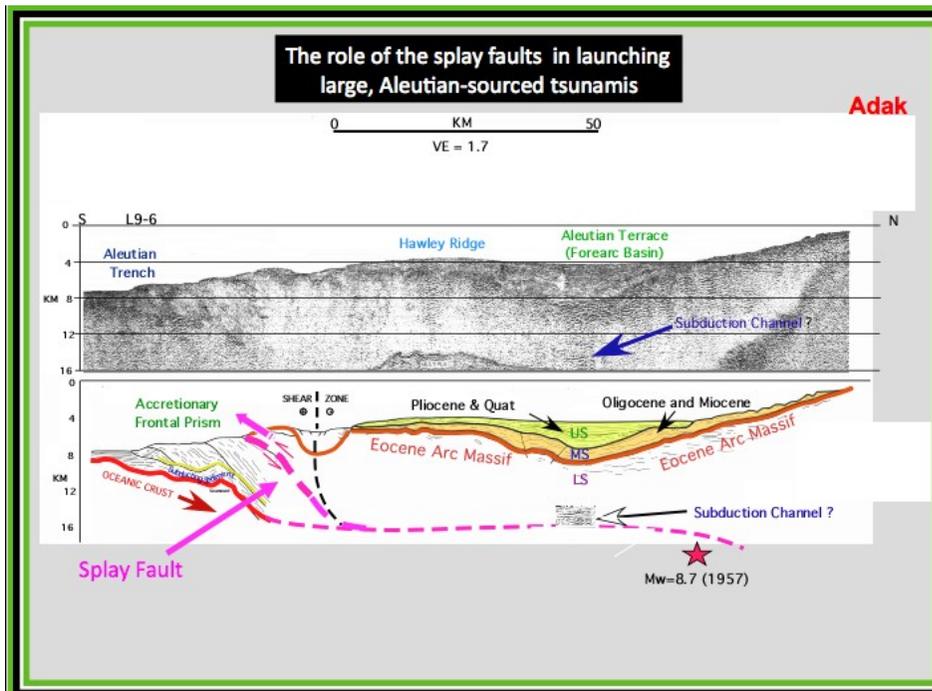
THE ALEUTIAN-ALASKA MEGATHRUST SETTING

The Aleutian-Alaska subduction zone is one of the world’s most seismically active and also the home of repeated great and giant earthquakes and matching tsunamis. Many factors are involved in setting up this reality, but those that promote long run-out megathrust events and rapid seaward interplate slipping can be linked to the circumstance that:



- 1) Subducted, high-standing ridges and large seamounts are widely spaced beneath the Aleutian-Alaska forearc—a circumstance favoring long-running ruptures.
- 2) The trench axis from Middleton Island, eastern Gulf of Alaska, 3200 km westward to Attu Island is, except for the Shumagin sector thickly charged (~2 km) with sediment shed from glaciated Alaskan drainages—a circumstance favoring lateral rupture continuation

- 3) Much of the length of the submerged Aleutian-Alaska forearc is underlain by large, structurally deep forearc basins—a circumstance that localizes rapid trenchward slip beneath them and the generation of regional and areally larger tsunamis (Well et al, 2003).
- 4) The Aleutian nearshore forearc is sheared by high-angle, nearshore reverse faults, and the Aleutian outer forearc by splay faults—circumstances favoring the launching of large localized tsunamis by reverse faulting and trans-oceanic tsunamis by splay faulting.



INFORMATION NEED TO MITIGATE CONSEQUENCES OF SEISMIC GEOHAZARDS

To mitigate the consequence of marine geohazards generated at the Aleutian-Alaska subduction zone, in particular large tsunamis, field knowledge is needed to make probabilistic estimates (forecasts) of their likely future occurrence and source regions. This essential information, which is largely or wholly missing, is acquired by a blend of coastal and offshore field studies to reveal the late Cenozoic history of great and giant earthquakes (the paleoseismic and -tsunamic record) and to regionally map the location, continuity, and geometry of forearc fault systems.

Specifically, what is needed for the entire length and width of the submerged forearc is:

- 1) High-resolution, multibeam bathymetric maps adequate, for example, to laterally trace fault scarps, identify middle and frontal prisms and splay faults separating them, slope failures, debris flows, and paths of subducted relief.

- 2) Information about when and where great and giant megathrust earthquakes nucleated.

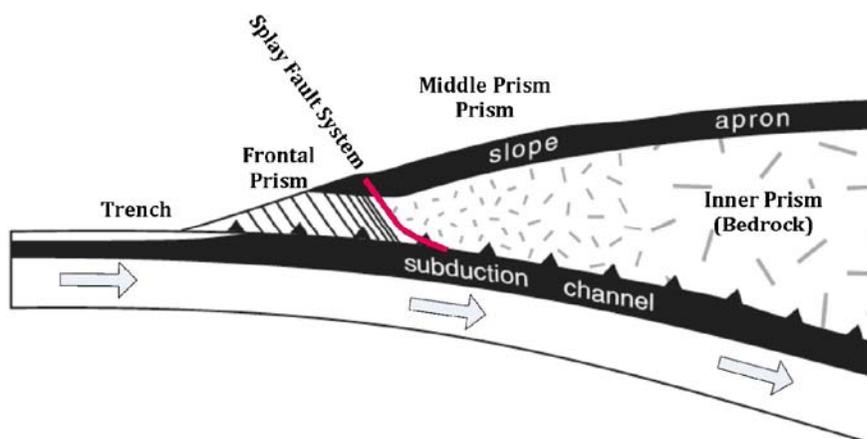
- 3) Information about when, where, and source-cause of local, extra-regional, and trans-oceanic tsunamis.

- 4) Information about the geometry and shape of the interplate surface and locations of significant along-strike changes.

- 5) Information about the location, geometry, and lateral continuity of high-angle reverse, splay, and strike slip fault systems.

- 6) Information about the causes of rupture segmentation (limits and termination).

- 7) Information about the thickness of sediment entering the subduction zone and within the subduction channel with respect to the relative height of underthrusting seafloor relief and roughness.



REFERENCES

- Ruff, L., 1989, Do trench sediments affect great earthquakes occurrence in subduction zones, *Pure and Applied Geophysics*, v. 129, Nos. 1/2, p. 263-282].
- Wells, R.E., R. J. Blakely, Y. Sugiyama, D. W. Scholl, and P. A. Dinterman, 2003, Basin-centered asperities in great subduction zone earthquakes--a link between slip, subsidence and subduction erosion?: *Journal of Geophysical Research*, v. 108, No. B10, 2507, doi:10.1029/2002JB002072