

# Off-trench Earthquakes in Alaska and Their Tectonic Significance

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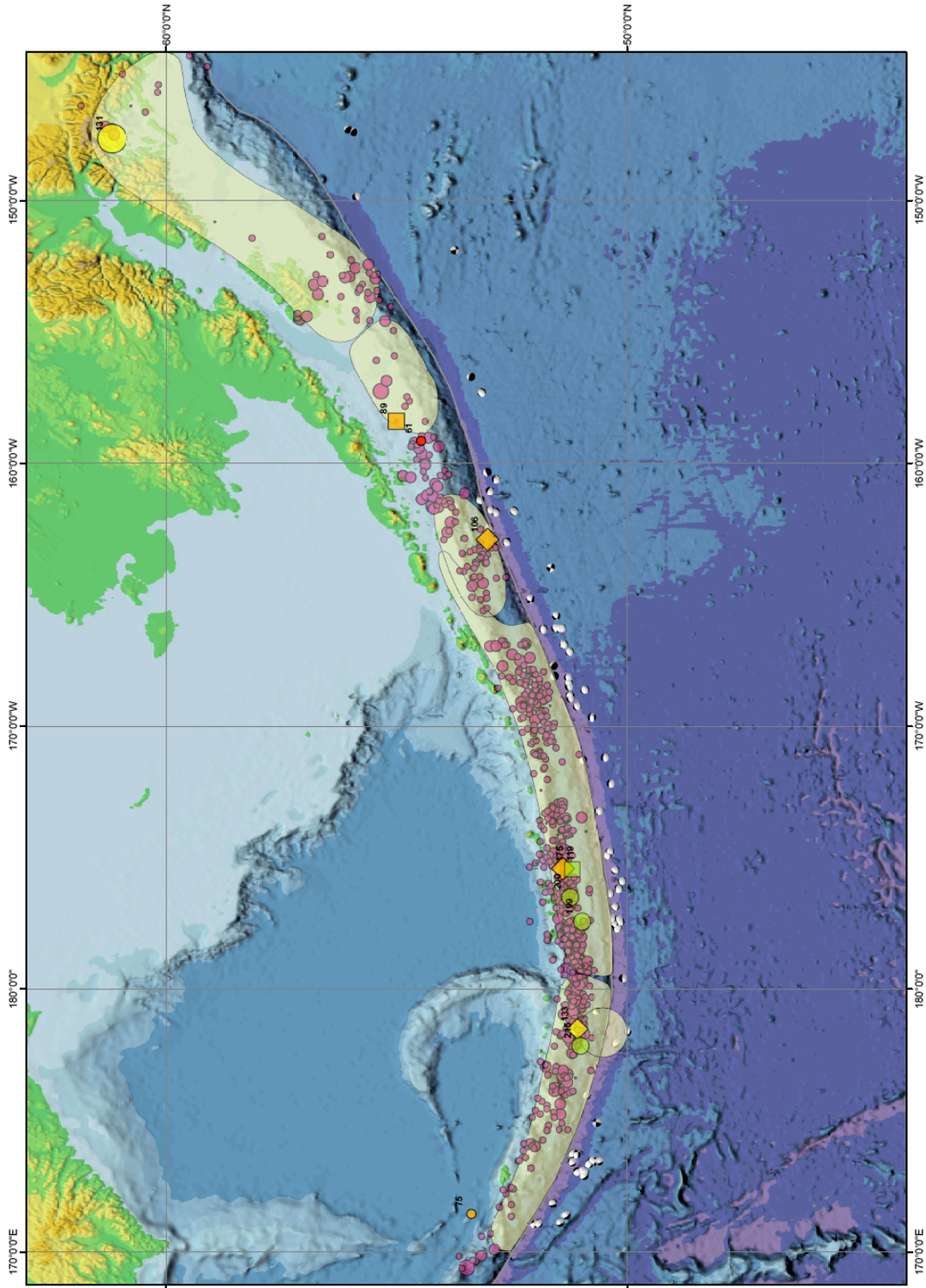
Off-trench normal-faulting earthquakes were first described by William Stauder in 1968 as a consequence of bending deformation of oceanic lithosphere as it descends into trenches, using as the first examples the off-trench events in the Aleutians. In the 43+ years since that discovery, thousands of such earthquakes have been documented in the instrumental record worldwide and hundreds pre-1968 events have been relocated definitively to the outer-trench-slope/outer-rise region. These earthquakes are important for several reasons. First, for exceptional great events of this kind, they represent potential tsunami sources in the near and far fields, such as the M8.1 event 2009 in Tonga/Samoa and the 1933 Sanriku earthquake in Japan. Second, they reflect the potential for great and giant interplate thrust earthquakes because many occur following such megathrust events and some may represent long-live aftershocks of giant off-trench events in the past. Third, they represent at least temporary sources of seafloor roughness that can cause tectonic erosion of the base of subduction forearcs and thereby affect the structure of the megathrust boundary and long-term forearc kinematics. Fourth, their focal mechanisms reflect not only bending stresses referenced to the local orientation of the trench axis, but also a faulting anisotropy inherited from the plate history of seafloor spreading and regional stresses associated with subduction obliquity (Mortera-Gutiérrez et al., 2003). We focus on these aspects of off-trench events for the Alaska/Aleutian margin.

In Alaska, hundreds of off-trench earthquakes with reliable epicenters have occurred in the instrumental era. Most of these events have occurred west of the Shumagin Islands where the Pacific Plate is older, thicker, and presumably more resistant to flexure. Among these, there are less than a hundred earthquakes large enough to have published focal mechanisms. Most of these earthquakes have normal faulting mechanisms (See map figure) with some tendency in the eastern Aleutians to have nodal planes skewed toward the generally E-W orientations of magnetic anomalies and away from the local trench azimuths, indicating a strong mechanical influence of seafloor spreading fabric. This deviation from strict parallelism with trench azimuths is also consistent with the trends of fault scarps revealed by the USGS Gloria surveys (Masson, 1991; Mortera-Gutiérrez *et al.*, 2003). There are also some scattered strike-slip mechanisms, including the remarkable sequence of strike slip earthquakes in 1987 and 1988 and their aftershocks in the Gulf of Alaska. Remarkably, even in the western Aleutians where relative plate motions are largely trench parallel, most events are normal faulting, although nodal planes are skewed away from the trench axis by the regional shear couple. The largest off-trench earthquakes occurred in 1929 (Kanamori, 1972) and 1965, both with moment magnitudes of about 7.8. Noteworthy blooms of off-trench earthquakes occurred after the giant megathrust earthquakes of 1957 (Mw ~8.6; Johnson and Satake, 1993) and 1965 (Mw 8.7; Kanamori, 1977) along the sectors of greatest megathrust slip, presumably caused by a kinematic transfer by megathrust slip that increases flexural deformation in the Pacific Plate. How slow block rotations in the forearc affect the stress state of the off-trench Pacific Plate has not been established.

## References Cited

- Kanamori, H. (1977), The Energy Release in Great Earthquakes, *Journal of Geophysical Research* 82, 2981-2987.  
Kanamori, H. (1971), Mechanism of Tsunami Earthquakes, *Phys. Earth Planet. Interiors* 6, 346-359.  
Masson, D. G. (1991), Fault patterns at Outer Trench Walls, *Marine Geophysical Researches* 13, 209-225.  
Mortera-Gutiérrez, C.A., Carlson, R, and Scholl, D., 2003, Fault trends on the seaward slope of the Aleutian Trench: Implications for a laterally changing stress field tied to a westward increase in oblique convergence: *Journal of Geophysical Research* 108, NO. B10, 2477, doi:10.1029/2001JB001433

Stauder, W. (1968), Tensional Character of Earthquake Foci beneath the Aleutians Trench with Relation to Sea-Floor Spreading, *Journal of Geophysical Research* 73, 7693-7701.



**Caption:** Focal mechanisms of off-trench earthquakes in Alaska (upper hemisphere) and epicenters of large megathrust boundary earthquakes (pink filled circles). The colored filled squares and circles represent notable large megathrust earthquakes and the light green filled “sausages” represent aftershock zones of great and giant megathrust earthquakes (USGS/NEIC). Note that most off-trench events occur west of 160°W longitude and hence off the Aleutian archipelago where the bending lithosphere is older. Most off-trench events show normal-faulting mechanisms and a small number of strike-slip and reverse-faulting mechanisms.