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Rapid Forearc Basin Subsidence and Bordering Splay Fault Systems may identify Nucleation Areas of High-Magnitude Earthquakes and Tsunamis—The Example of the Atka forearc basin sector of the Aleutian Subduction Zone

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INTRODUCTION: The Aleutian subduction zone (SZ) is one of Earth's most seismically and volcanically active convergent margins. The sweep of this SZ across the northern Pacific rim poses a great tsunami threat to the coastal communities of the north Pacific rim, the Hawaiian Islands, and island communities to the south. The setting of especially dangerous segments, for example the Atka forearc basin sector off the Aleutian Islands, appears to be linked to the subducting geometry, relief, and sediment cover of the underthrusting Pacific plate.

OBSERVATIONS: During the past 53 years three high-magnitude (Mw 7.9, 8.0, and 8.7) megathrust earthquakes nucleated in the vicinity of the deep water, bathymetrically prominent Atka forearc basin of the Aleutian Ridge. Atka Basin is the deepest (3-5 km) sector of the ∼1500-km-long forearc basin of the Aleutian Terrace. The sector is obliquely underrun toward the west by the subducting Pacific plate. During each of the megathrust events the highest slip (moment release) occurred beneath the axial area of the Aleutian forearc basin, with two of the events located beneath Atka Basin. Both ruptures launched destructive trans-Pacific tsunamis. Offshore dredging and DSDP drilling establish that Atka Basin is a young, rapidly subsiding structural depression filled with 2-3 km of latest Miocene and younger deposits. The axis of deposition has migrated arcward (north) and westward with time. To the south, the basin is fronted by Hawley Ridge, an outer forearc antiformal high. The ridge is bordered along its trenchward side by a right-lateral shear zone and a more seaward splay fault system that thrusts arc-framework rock southward over a frontal prism of accreted trench deposits. GPS studies document that the subduction zone is effectively locked beneath the deepening Atka Basin and rising Hawley Ridge, but effectively unlocked to the east where the forearc basin of the Aleutian Terrace is structurally inverting and large megathrust earthquakes have not been recorded. These adjacent sectors of the Aleutian forearc basin are separated by the underthrusting Amlia Fracture Zone, which is migrating westward with the obliquely underthrusting Pacific plate. West of the Amlia FZ (beneath Atka Basin) the underthrusting plate is younger (∼15 myr), dips less steeply, and is bathymetrically rougher than the Pacific plate underrunning the low-seismicity forearc east of the subducting FZ.

CONJECTURE: Most likely, the rapid deepening of Atka Basin is an expression of crustal thinning caused by an enhanced rate of basal subduction erosion linked to low-angle underthrusting of the Pacific plate. The lateral rupture propagation necessary to generate great earthquakes is facilitated by the insertion of a thick (1.5-2.0 km), continuous section of axial trench sediment into the subduction channel. It can be conjectured that the presence of a young, actively subsiding forearc basin bordered by a splay fault system and underthrust by a sediment-charged subduction channel may identify where high magnitude earthquakes repeatedly nucleate and potentially launch destructive tsunamis.