Variations in Seismicity Along the Central Aleutian Arc: An Opportune Site for GeoPRISMs Research

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Introduction

Despite the abundant seismic activity along the Alaska-Aleutian subduction system as a whole, several sections of the megathrust have not produced large-magnitude seismic events in recorded history, and display different seismic behavior. The Shumagin "gap" is perhaps the most-often cited of these anomalous segments. The Amlia region further west, near Seguam and east of Atka and Amlia islands, is also an apparent or possible seismic "gap", with lower levels of background seismicity (Fig. 1) and only limited rupture during past great earthquakes (e.g. House and Jacob, 1983). This region also has documented distinct geochemical variations along-strike that are spatially correlated to the observed structural and seismogenic variation.

This white paper advocates for tightly-coupled studies of seismicity, deformation, subduction zone structure (slab, arc, fore-arc, mantle wedge), and geochemistry of the arc within the Amlia-Andreanof region. Detailed studies here have the potential to aid in distinguishing between proposed down-dip limits on the seismogenic zone (e.g. the Moho vs. a temperature limit), will characterize the physical and seismic properties of a megathrust boundary that has produced multiple large earthquakes in recorded history, and determine how these properties transition into a seismically quiescent segment, both in terms of background seismicity from 1960-present and great earthquakes.

Tectonics and seismicity of the central Aleutian margin

The Rat and Andreanof Islands regions, including the Amlia sector, form part of the intra-oceanic Aleutian arc within the transition from nearly orthogonal plate convergence to convergence with a significant arc-parallel component. Fore-arc and summit basins preserve a history of oblique plate convergence and deformation. The 1957 (Mw 8.6), 1965 (Mw 8.7), 1986 (Mw 7.9) and 1996 (Mw 7.9) earthquakes nucleated within the central Aleutian arc and ruptured much of the plate boundary (Tarr et al., 2010). However, an abrupt change in seismicity occurs near 173°W, correlating with the intersection of the Amlia Fracture Zone (AFZ) with the oceanic trench. Rupture during the 1986 earthquake did not continue east of this boundary, and although the 1957 earthquake ruptured across this segment, a lack of aftershocks in the zone immediately east of the AFZ (Boyd et al., 1995; Okal, *personal communication*, 2009) suggest that the rupture may have jumped the segment with little strain release. GPS data and modeling suggest that a section of the megathrust may be freely slipping in this area (Cross and Freymueller, 2007), possibly similar to the Shumagin region ~900 km to the northeast (Fournier and Freymueller, 2007). Variability in recorded seismicity and cumulative moment release from 1960-present along-strike in this region is pronounced (Fig. 1), suggesting a possible discontinuity in the properties of and/or coupling at the plate interface.

Multi-channel seismic reflection data from USGS studies (1980 and 1981) crossed the trench and fore-arc, and an Ewing cruise in 1994 crossed the central Aleutian trench, fore-arc, and volcanic arc. These reflection data, combined with satellite gravity and magnetic data, indicate a distinct and systematic difference in slab, mantle wedge, and upper-plate structure/properties between the segments of the margin that display varying seismogenic behavior. Slab dip is shallow beneath the Andreanof Islands west of the AFZ (Ryan and Scholl, 1989), and steepens abruptly east of the fracture zone (Holbrook et al., 1994). Deformation within forearc sediments transitions from compressional in the western segment to extensional on the eastern side, and the spacing between adjacent volcanoes is disrupted as is the trench-volcano distance at the AFZ (e.g. Nye et al., 2010). To the west of this transition, the mantle wedge produces a higher-amplitude magnetic anomaly than east of the AFZ (Blakely et al., 2008). The subdued magnetic anomaly could indicate a lack of serpentinite, or alternately, higher temperature (above 580°C) in the mantle wedge east of the AFZ. Geochemical data from the volcanic arc support and reflect the systematic variation in structure observed in geophysical data (e.g., Singer et al., 1996; 2007; Jicha et al., 2004). Seguam volcano, above the seismically anomalous segment east of the AFZ, indicates an order of magnitude higher degree of partial melting than nearby volcanoes (Jicha et al., 2004). The arc west of the AFZ typically has small-volume, crystal-rich calcalkaline magmas which are andesite to dacite in whole-rock composition with dacite to rhyolite groundmass glass. In contrast, the segment east of the AFZ contains volcanoes which are larger, basaltic andesite to andesite, tholeiitic, with dramatically lower crystal contents and more mafic groundmass glass (Nye et al., 2010).

The correlation between the abrupt change in the number of earthquakes with the distinct transition in geochemistry and slab, upper-plate, and mantle wedge structure suggests that the thermal structure of the upper mantle, melt generation, and melt pathways change across this transition as the slab decouples from the upper plate east of the AFZ.

Summary

Studies integrating the structure and thermal/geochemical/rheological properties of the central Aleutians/Amlia region with amphibious studies of local seismicity and plate coupling will provide critical insight into the governing factors on the ‘size, location and frequency of great subduction zone earthquakes, and the relationship to the spatial variation of slip behavior observed along subduction faults’ (Science Plan objective 4.1). Results from the Amlia region will be most valuable when compared to and integrated with results from previous (Nedimovic et al., 2003) and current (Nedimovic et al., 2011; Shillington et al., 2011) studies of changes in seismogenesis at the plate interface, e.g., at Cascadia and in the Shumagins, respectively. Detailed studies in locations with different parameters (oceanic vs. continental margins, direction and speed of convergence, age of the plate, etc.) will aid in the discrimination of globally vs. locally important controls on seismogenesis. Additionally, the detailed nature of the spatial correlation of the distinct geochemical variation along-strike to observed structural and seismogenic variations (Nye et al., 2010) is an intriguing research target. The variability is proposed to reflect varying stress state and migration pathways for melts, affecting the transfer and release of these fluids within the subduction system and the ultimate geochemical products of the system (Science Plan objectives 4.4,4.5).

We suggest that further research in the central Aleutian arc, particularly spanning the Amlia Fracture Zone, may lead to significant advances in our understanding of subduction processes, seismogenesis, and arc construction.

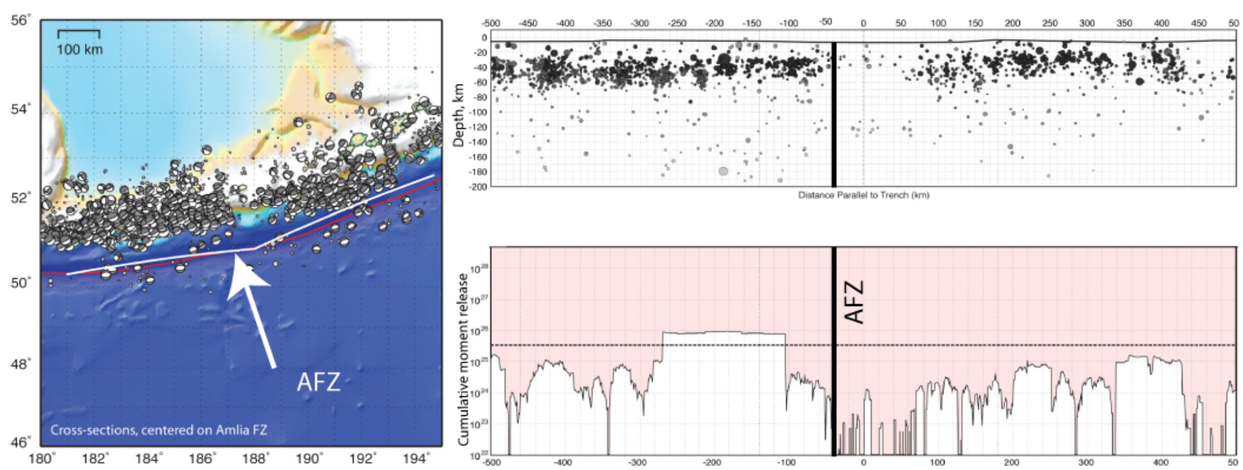

Figure 1: Gap in seismicity (1960-present) and cumulative moment release east of the Amlia Fracture Zone (images courtesy of G. Hayes, NEIC).