GeoPRISMS Planning Workshop for the Alaska Primary Site White Paper: An Aleutian Seismological Observatory

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The Aleutian Islands are an attractive target for dense small-aperture USArray Flexible Array deployments, as volcanic and subduction zone seismicity rates are high but island geography severely limits sub-aerial geophysical data coverage. Akutan and Unalaska Islands are ideal sites for USArray to reach into the Aleutians for six principal reasons: 1. The area has a rich variety of seismic sources at a variety of depths with both tectonic and volcanic origins, 2. The islands are located at the transition between subduction of continental and oceanic lithosphere, near the eastern edge of 1957 M8.6 megathrust rupture zone, 3. Dense array studies would compliment ongoing USGS, AEIC, and PBO monitoring efforts in the region and could potentially dovetail with other multidisciplinary GeoPRISMS and EarthScope projects, 4. Akutan and Makushin are among the most frequently active volcanoes in the United States and are defined as 'very high threat' volcanoes by Ewert et al. (2005), 5. Unalaska is the most populated Aleutian Island, and current development of a new airport and geothermal power plant in the region promises continuing growth of critical north Pacific infrastructure here, 6. Unlike some islands in the Aleutians, the field logistics here are tenable, and land use permitting is relatively straight forward as these islands are not classified as wilderness areas.

Dense small-aperture seismic arrays installed on Akutan and Unalaska Islands could potentially have multiple targets. The subduction zone beneath Akutan and Unalaska Islands has been the most prolific producer of detectable deep non-volcanic tremor (NVT) in the Aleutian arc in the past decade (Brown et al., 2011., Peterson et al., 2005). NVT generally locates at the down-dip edge of the 1957 rupture zone (Figure 1). A spectacular case of triggered tremor occurred in this region during the surface wave arrivals of the M 9.0 Tohoku-Oki earthquake (Rubenstein et al., 2011). Despite recent progress in our understanding of NVT in this region, its temporal and spatial extent and relationship to earthquakes and slow slip is not well resolved. Attractive volcanic targets exist in this area as well, which offer excellent opportunities to partner with GeoPRISMS to study the interplay between the subduction zone and volcanic processes in the crust and upper mantle. For example data from dense arrays could be used to refine the velocity tomography of Syracuse et al. (2010). Akutan volcano had the largest seismic response to magmatic intrusion of any Alaskan volcano in the history of local monitoring, when

more than 200 earthquakes ≤ M 3.5 (M_{max} 5.1) occurred during a shallow magmatic intrusion in 1996 (Lu et al., 2005). Akutan and Makushin volcanoes are a persistent source of deep (10-45 km) volcanic long-period (LPs) earthquakes as well (Power et al., 2004). The source process and locations of deep LPs are difficult to constrain with data from current seismic networks, yet these events are thought to be related to magma transport. Further study of deep LP's with dense seismic arrays, particularly if tied to geochemical studies, would further our understanding of magma generation and ascent in a volume of crust where these processes are poorly resolved. Deep LPs have the potential to be used as intermediate term precursors to volcanic eruptions.

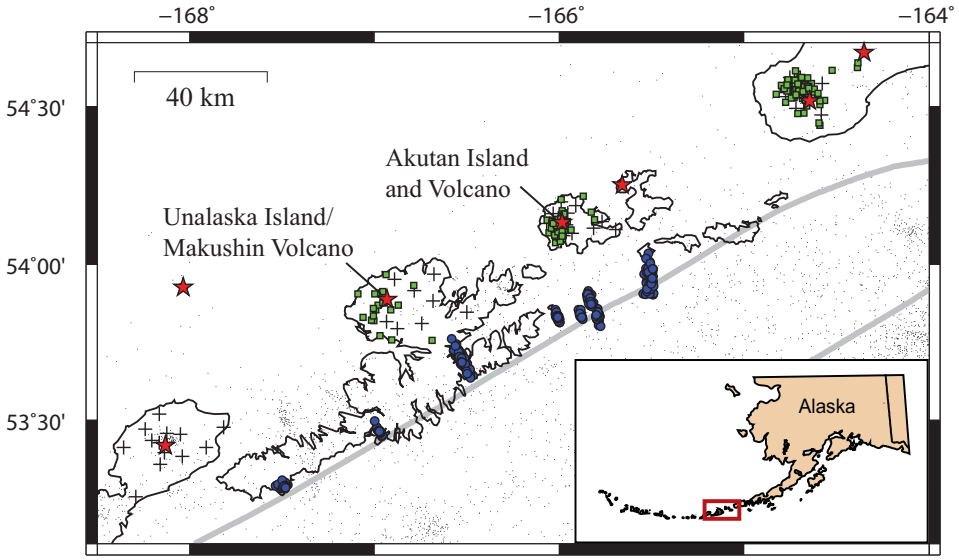

Figure 1 – *Target events for small-aperture arrays. Blue circles are locations of low-frequency events within NVT (Brown et al., 2010). Green squares are deep (10-45 km) long period earthquakes. Crosses are existing seismic stations. Red stars are volcano summits. Gray line shows M8.6 1957 rupture zone. Dots show ANSS catalog M2+ earthquake locations 2002-2010. Red box in inset map shows location in Alaska.*

Given this suite of seismic targets and following Ghosh et al. (2009, 2011), data from several dense seismic arrays on Akutan and Makushin Islands could potentially refine our understanding of the spatial and temporal characteristics of NVT near the end of a rupture zone, illuminate volcanic system structure and earthquake sources at Akutan and Makushin volcanoes, and constrain the relationship between earthquakes, subducted slab composition and structure, and magma genesis and transport. One advantage of the multi-beam back projection method is that it can track the migrating source, volcanic or non-volcanic, in high resolution over different time scales. We suggest that a suitable Flexible Array deployment in this region could consist of four or more 10-15 sensor arrays located above known NVT and deep LP sources.

Brown, J.R., S.G. Prejean, G.C. Beroza, J.S, Gomberg, and P.J. Haeussler (2010) Evidence for deep tectonic tremor in the Alaska-Aleutian subduction zone, EOS 91, 2010 AGU Fall Meeting.

Ewert.,J.W., M. Guffanti, and T. L. Murray (2005), An Asseessment of volcanic threat and monitoring capabilities in the United States: Framework for a National Volcano Early Warning System: USGS Open-File Rep., 2005-1164.

Ghosh, A., J. E. Vidale, and K. C. Creager (2011) Tremor depth using Array of Arrays in Cascadia, 2011 SSA Annual Meeting.

Ghosh, A., J. E. Vidale, J. R. Sweet, K. C. Creager, and A. G. Wech (2009), Tremor patches in Cascadia revealed by seismic array analysis, Geophys. Res. Lett., 36, L17316, doi: 10.1029/2009GL039080.

Lu, Z., C. Wicks, O. Kwoun, J.A. Power, D. Dzurisin (2005), Surface Deformation associated with the March 1996 earthquake swarm at Akutan Island, Alaska, revealed by C-band ERS and L-band JERS radar interferometry, Can. J. Remote Sensing, 31, p 7 -20.

Peterson, C., D. H. Christensen, and S. McNutt (2005), Episodic tremor in the Alaska/Aleutian subduction zone, EOS 86, 2005 AGU Fall Meeting.

Power, J.A., Stihler, S.D., White, R.A., Moran, S.C. (2004), Observations of deep long-period (DLP) seismic events beneath Aleutian arc volcanoes; 1989-2002, J. Volcanol. and Geotherm. Res., 138, p. 243-266.

Syracuse, E.M., C.H. Thurber, J.A. Power, and S.G. Prejean (2010) Three-dimensional velocity structure and high-precision earthquake relocations at Augustine, Akutan, and Makushin Volcanoes, Alaska, EOS 91, 2010 AGU Fall Meeting.

Rubenstein et al., (2011) Widespread triggering of earthquakes and tremor by the 2011 M9.0 off-Tohoku earthquake, 2011 SSA Annual Meeting.