FlexArray Alaska: Basin-to-slab seismic imaging of subduction tectonics

Carl Tape[1], Stéphane Rondenay[2], Doug Christensen[1]

[1] Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska, USA
[2] University of Bergen, Bergen, Norway

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Abstract

Forearc basins are fundamental components of convergent margins, both accretionary and erosive. However, crustal, slab, and upper mantle structure in the vicinity of these basins are not well imaged by traditional seismic techniques, because the basins trap seismic waves, thereby obscuring subtle signals that originate from target structures below. We propose a deployment of 30 FlexArray broadband seismic stations in the vicinity of Cook Inlet basin to image a slab-normal subduction profile that extends from the locked zone of the 1964 M_w 9.2 earthquake, through the Cook Inlet forearc basin, through the active volcanic arc (Redoubt), and 100 km into the backarc region. Our seismic imaging technique utilizes spectral-element and adjoint methods which rely on highly accurate wavefield simulations within three-dimensional models. These techniques should allow us to better image the extreme structural complexity of this region, as manifested in full-length, three-component seismograms. Motivated by the striking spatial patterns in shear-wave splitting from previous deployments in Alaska (BEAAR, MOOS), we will broaden these observations to help understand how the anisotropic fabric changes across the subduction zone. Our overarching question is:

> What are the relationships among basin formation, active crustal faults, slab geometry, and mantle dynamics in subduction systems? Specifically, how is the formation of Cook Inlet forearc basin related to the dynamics of the Alaska-Aleutian subduction zone?

A targeted broadband array of stations, combined with seismic wavefield modeling, could exploit the phenomenal slab and crustal seismicity, and would provide a golden opportunity for producing a detailed structural model of the subduction zone. Such a model could serve as a basis for geodynamical and geochemical models.

The project would provide promising targets for complementary 2D and 3D active-source marine experiments within Cook Inlet and oceanward of Seward Peninsula toward the trench.

Fundamental objectives

1. What is the 3D structure of the subduction zone (basin, slab, crust, arc, upper mantle) in the region of Cook Inlet forearc basin (Figure 1)?
2. What is the anisotropic structure: (1) below the slab, (2) within the slab, and (3) above the slab?
3. What are the modes of deformation inferred from source mechanisms of local intraslab and crustal earthquakes?
4. How does sub-arc and sub-basin seismicity (Figure 1) connect to the slab below and the surface geological deformation above?
5. How is the formation of the forearc basin related to the surface and subsurface dynamics of the subduction zone?

Scientific tasks

1. Build an initial 3D upper mantle and crustal model of the subduction zone in Alaska.

2. Build an initial high-resolution 3D model of the crust and upper mantle in the vicinity of Cook Inlet forearc basin.

3. Collect 2–3 years of waveform data from 30 temporary broadband stations and ∼20 permanent broadband stations in the Cook Inlet region.

4. Use spectral-element and adjoint methods within a tomographic inversion to iteratively improve the high-resolution 3D models (*Tape et al.*, 2009).

5. Use local shear-wave splitting to determine anisotropic structure in the mantle wedge or crust. Compare with previous SKS splitting results (*Christensen and Abers*, 2010).

6. Use generalized radon transform or receiver function analysis to identify primary interfaces (Moho, slab), in addition to those within the upper mantle and crust. Such techniques have proven successful on Alaska data sets (*Ferris et al.*, 2003).

7. Investigate the relationships among slab seismicity, crustal seismicity, gravity anomalies, and the formation of the basins (e.g., *Wells et al.*, 2003; *Haeussler and Saltus*, 2011).

8. Relocate crustal and uppermost mantle seismicity in order to refine the deformation zones below forearc basin and arc.

9. Perform targeted 2D and 3D imaging of the Cook Inlet subducting slab (e.g., *Rondenay et al.*, 2008). What can the images (in combination with seismicity) tell us about the compositional and thermal structure of the slab?

References

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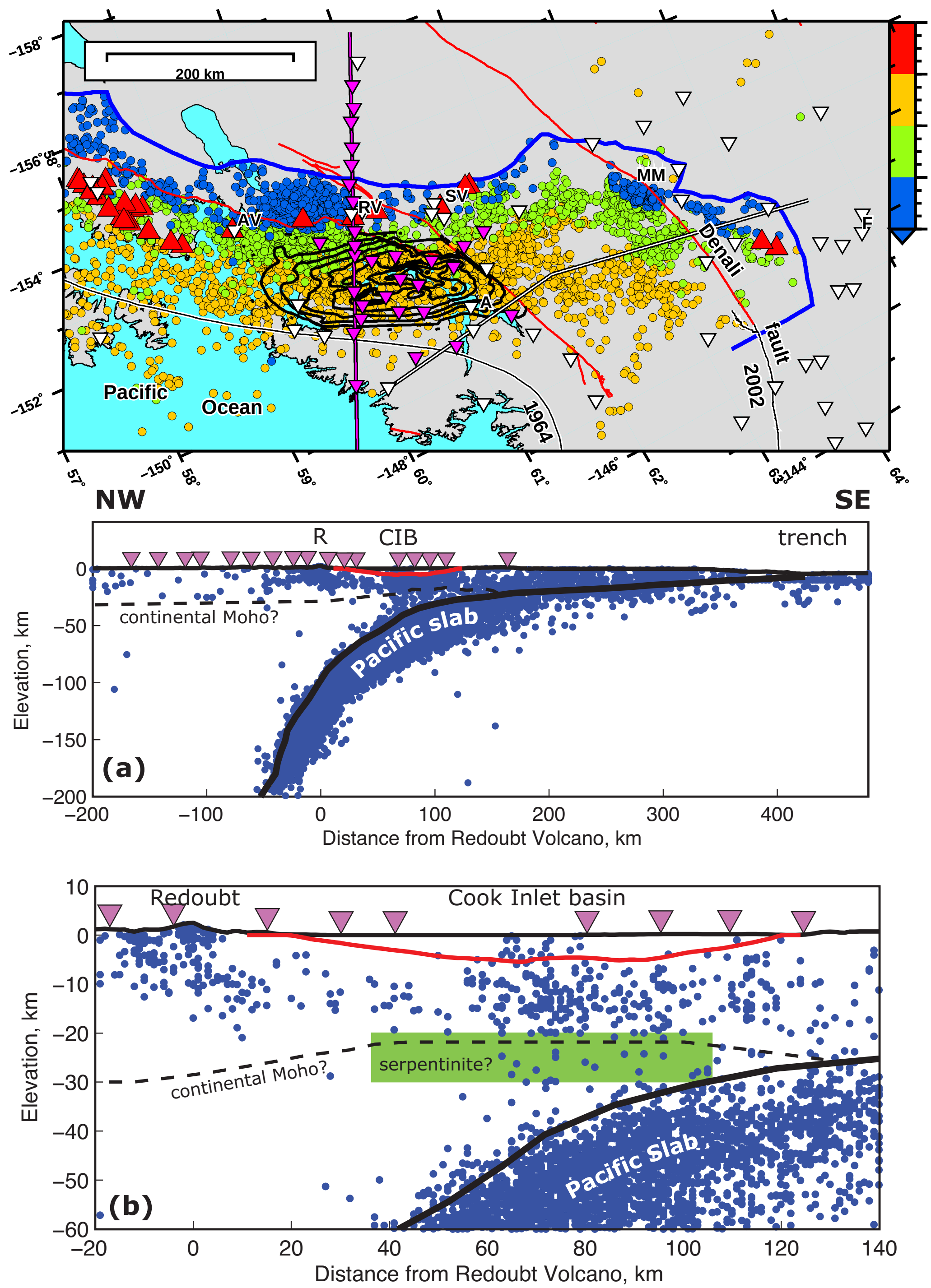

Figure 1: Proposed FlexArray seismic deployment in the Cook Inlet region, southern Alaska. **(top)** Slab seismicity (depth $>$ 40 km, $M > 3$, 1990–2010) illuminates the subducting Pacific plate; active volcanos are plotted as red triangles. In this oblique perspective, north points to upper right. Permanent broadband seismic stations are plotted as solid inverted triangles; proposed FlexArray stations are plotted as open inverted triangles. Target subduction profile contains Redoubt volcano and Cook Inlet basin, whose basement contours are plotted in black (max depth = 7.6 km). Labels: AV = Augustine volcano, RV = Redoubt volcano, SV = Spurr volcano, MM = Mt. McKinley, A = Anchorage, F = Fairbanks. Aftershock zones for the 1964 M_{w} 9.2 and 2002 M_{w} 7.9 earthquakes are plotted. The two segments show the approximate trend of previous PASSCAL arrays (MOOS, BEAAR). **(a)** One-to-one perspective of the full profile. **(b)** One-to-one perspective of the section emphasized in this proposal. Notice the seismicity within and below Cook Inlet basin, in addition to pervasive seismicity beneath Redoubt volcano and within the Pacific slab. Proposed serpentinite body is based on gravity and magnetic modeling.