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Long streamer waveform tomography imaging of the Sanak Basin, Alaska subduction zone

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The Alaska subduction zone is prone to large megathrust earthquakes, including several large tsunamigenic events in the historical record (e.g. the 1964 Mw 9.2 and the 1946 Mw 8.6 earthquakes). Along the Alaska Peninsula trench, seismic coupling varies from fully locked to the east to weakly coupled to the West, with apparent aseismic slip in the Shumagin Gap and Unimak rupture zone. Overlapping the Shumagin gap and the Unimak area, the Sanak basin is a Miocene basin formed by a large-scale normal fault recently imaged by the ALEUT 2011 cruise and clearly rooting in the subduction interface at ∼30 km depth (Becel et al., submitted). Recent activity on this normal fault is detected at the seafloor of the Sanak Basin by a ∼5 m scarp in the multibeam bathymetry data. As this normal fault may be associated with faults involved in the 1946 tsunami earthquake, it is particularly important to try to decipher its history in the Sanak basin, where sediments record the fault activity.

MCS data processing and interpretation shows evidence for the activity of the fault from Miocene to recent geological times. Very limited knowledge of the sedimentation rates and ages as well as complexities due to submarine landslides and channel depositions make it difficult to quantify the present day fault activity with respect to the Miocene fault activity. In addition, the mechanical behaviour of a normal splay fault system requires low to zero effective friction and probably involves fluids. High-resolution seismic velocity imaging can help with both the interpretation of complex sedimentary deposition and fluid detection.

To obtain such a high resolution velocity field, we use two 45-km-long MCS profiles from the ALEUT 2011 cruise acquired with an 8-km-long streamer towed at 12 m depth to enhance low frequencies with shots fired from a large, tuned airgun array (6600 cu.in.). The two profiles extend from the shelf break to mid slope and encompass the normal splay fault emerging at ∼1 km water depth. At these depths, refracted arrivals are recorded on the second half of the streamer and a traveltime tomography inversion of the first refracted arrivals is possible. To quantify the uncertainties of the inversion results, starting from a smoothed RMS velocity model from the reflection data analysis, we perform a Monte-Carlo analysis using 360 randomly perturbed initial models and perturbed traveltime picks. We use the converging models as input for a Monte-Carlo analysis of acoustic frequency domain waveform tomography. We show that the model resolution is high in the faulted area (∼100m) and the uncertainty is low. We image a complex pattern of low velocities around and away from the fault corresponding to mass transport deposits and possible fluid flow through the fault, in agreement with low reflectivity of the multibeam data and the presence of pockmarks.