Deep Structure of the Northern Cascadia Subduction Zone From Multichannel Reflection and Tomography Studies

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A disastrous megathrust or crustal earthquake is a very real threat to the growing population in the southwestern British Columbia and the northwestern Washington State. In 1998, a multidisciplinary seismic survey named SHIPS (Seismic Hazards Investigation in Puget Sound) was carried out by USGS, GSC, and six universities to study the structure of this region. The main objective was to map active crustal faults in the Straits of Juan de Fuca, Georgia Straits and Puget Sound, and to gather information about earthquake controlling structures, including the position and nature of the subducted oceanic slab. The survey in inland waterways resulted in 1000 km of seismic reflection profiles and a dense wide angle data set covering the study area. Extracting seismic structure from reflection data collected in this environment was challenging. Reflections are masked by refracted and guided waves, by water-bottom and peg-leg multiples, by side-scattered energy, and by ship noise and other high-amplitude, broadband cultural noise. In contrast, first P-wave arrivals used for the tomography study were generally clear.

We carry out a comparative analysis of the obtained reflection and tomography results. Despite the low signal-to-noise ratio of reflection data, the images reveal several important structural features in the region. At shallow depths, for example, Leech River Fault is imaged both by reflection and tomography. On the reflection image, this fault can be traced a few kilometers closer to the surface than it was previously possible on an earlier Lithoprobe section. Shallow forarc sedimentary basins are outlined fairly well on reflection sections. The larger deep basins are imaged well by tomography. At greater depth, a thick reflector band is often present in the reflection images. This event correlates well with the "E" reflection evident in Lithoprobe sections. The oceanic crust, not visible in the seismic images, is known from seismicity to form an upward bulge beneath the Olympic Peninsula and the adjoining regions. However, the magnitude of arching is still a topic of debate. Because the E reflection band in our sections appears to occur at a similar vertical distance above the subducting Juan de Fuca Plate it represents a potential tool for indirect mapping of the subducted oceanic crust. We compare the E reflection band on seismic sections with the 7.5 km/s iso-velocity line on the corresponding tomography sections (which we believe approximately outlines the oceanic crust Moho). Our results show that both the E reflection band and the 7.5 km/s iso-velocity line dip towards north and east, in agreement with the existence of an upward bulge in the oceanic crust beneath northwestern Washington.