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Dispersion of regional body waves at 100-150 km depth beneath Alaska: In situ constraints on metamorphism of subducted crust

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Abstract. Phase delays at high frequencies are observed in body waves that travel in the Alaska slab, along its strike at 100-150 km depth. The delays, between 2-6 Hz energy and the direct 0.5-1 Hz arrival, are 0.5-1.5 s for *P* waves and 1.5-4 s for *S* waves. Such dispersion suggests a waveguide structure that parallels the slab, perhaps near its top. A channel that is 2-6 km thick and 2.5-5% slower than surrounding mantle can explain the observations. The thickness of the layer is comparable to that of subducted oceanic crust or somewhat thinner. The layer may be crust that is slow at these depths. The required velocity anomaly is too small to be due to a continuous layer of metastable gabbro yet too large to represent an eclogite layer. It may indicate a mixture of the two, or persistence of hydrated mineral assemblages to depth.

Introduction

Many of the first-order changes to subducting plate properties occur at depths greater than 50-100 km, where high-resolution observations are difficult. A variety of changes in material properties may affect subducted oceanic crust as it descends through these depths (e.g. Helffrich et al., 1989; Kirby, 1995) which can lead to large structural variations over length scales of 5 km or less. Unfortunately, this length scale is nearly impossible to image through travel time tomography because of the great depth to the relevant zone; even the most detailed current velocity models (e.g. Zhao et al. 1994) do not resolve features smaller than 30-50 km.

To resolve these small-scale structures within the subducted plate, the frequency dependence of wave propagation is analyzed here. Several studies of propagation from Tonga events to New Zealand (e.g. Ansell and Gubbins, 1986; Gubbins and Snieder, 1991) have shown strong dispersion of *P* wave trains. There, high frequency (>1 Hz) energy tends to arrive up to 15 s earlier, for some paths, than does a dominant long period arrival. A contrasting observation has been made in central Honshu, where waves traveling up dip along the slab show high frequencies delayed by up to 1 s relative to the first long-period arrival (Iidaka and Mizoue, 1991). The location of ray paths, and the frequencies involved, suggest that dispersion is a signature of subducted oceanic crust or nearby lithosphere, which is expected to undergo a series of phase transformations as it descends. Still, the observed difference in behavior is difficult to interpret in terms of dry rheologies (Gubbins et al., 1994). In the present study we analyze dispersive behavior for propagation in a slab beneath Alaska and find dispersion similar to that seen in Japan, of a low-velocity waveguide. Delay times are then used to place constraints on phase assemblages present in subducted crust.

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Observations

Data. We examine *P* waveforms for all events in the Alaska slab deeper than 100 km, for the years 1992 and 1993, recorded at Global Seismic Network station COL (Figure 1). These broadband records, recorded at 20 samples per second, have a flat instrument response to velocity at frequencies below 8 Hz. We use only waveforms with significant signal-to-noise levels at frequencies above 0.25 Hz, to resolve signal over a frequency span greater than one decade. This criterion gives 22 events at 300 to 800 km range from COL, where rays traverse the Alaska slab along strike, and 31 closer events from the region beneath Mt. McKinley where rays do not traverse the slab. All of these events are 100 – 170 km deep, and most are 100 – 120 km deep.

Rays and Arrival Times. In order to ascertain the nature of the first arrivals, travel times at COL are measured and com-

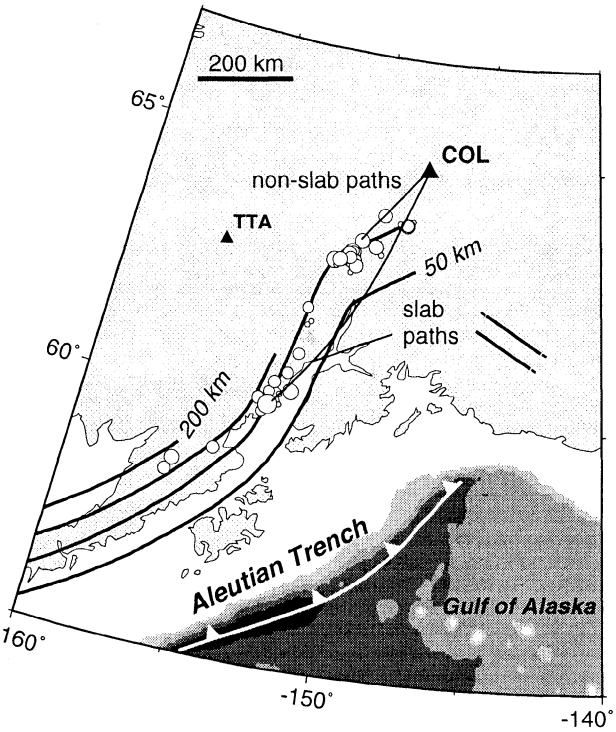

Figure 1. Map of Alaska slab, showing events used (circles, scaled to magnitude) and stations (triangles). Contours (thick lines) show depth to the Wadati-Benioff zone, from Page et al. (1989). Thin lines show examples of raypaths computed in the three-dimensional velocity structure.