MULTI-CHANNEL SEISMIC (MCS) DATA

MCS profile STEEP02 was acquired in September 2008 using the R/V Marcus Langseth. The profile was shot at 50-m shot spacing and recorded on a 8-km-long solid streamer with 640 channels at 12.5 m spacing. The sound source was an array of 36 air guns with a total volume of 6600 cubic inches, and source and receiver depth were both 9 m. All MCS data processing was performed using the FOCUS software package by Paradigm Geophysical. Within FOCUS we defined a basic marine geometry for the profile using 12.5 m receiver spacing, 50 m shot spacing, a near offset of 164 m, and 6.25 m CDP spacing. We resampled the data at 4 ms and applied a bandpass filter of 3-8-60-80 Hz. We applied a time-squared gain to compensate for amplitude loss due to spherical divergence. For deconvolution, we used a predictive operator with a 40 ms operator length. Velocity analysis was conducted at a 250 CDP interval. Finally, we migrated the data using a finite-difference technique with a maximum dip of 65 degrees and a smoothed velocity field (5000 m by 500 ms). Fig. DR1 shows the entire STEEP02 MCS profile, and Fig. DR2 displays an enlargement of the Transition fault region. To enhance display, we applied a variable depth gain with averaging over 1000 ms.

WIDE-ANGLE DATA

Observed Data

STEEP02 was shot at 150-m shot spacing for a coincident wide-angle seismic profile recorded by ocean bottom seismometers (OBSs) positioned at a seafloor spacing of ~15 km. Standard processing of the OBS data included applying a correction for clock drift during
deployment and inverting the direct water wave arrivals for instrument location (Christeson, 1995). Representative record sections of the STEEP02 ocean bottom seismometer (OBS) data are displayed in Figures DR3-DR6.

OBS 217 and OBS 213 are located on Pacific crust, 92 km and 17 km southwest of the Transition fault, respectively. Typical oceanic crust arrivals are observed northeast of OBS 217 (Fig. DR3a, positive offsets) and southwest of OBS 213 (Fig. DR4a, negative offsets), with a Pg crustal refraction observed as first arrivals to offsets of ~25-30 km and a prominent PmP Moho reflection at offsets 20-50 km. A Pn mantle refracted arrival is observed at offsets 35-55 km for OBS 213, with a possible faint Pn arrival at offsets 40-55 km for OBS 217. Arrivals not consistent with oceanic crust are observed northeast of OBS 213 (Fig. DR4a, positive offsets) and at long offsets northeast of OBS 217 (Fig. DR3a, offsets 150-200 km).

OBS 208 and OBS 201 are located on Yakutat block crust, 43 km and 148 km northeast of the Transition fault, respectively. First arrivals from shots <50-60 km offset have apparent velocities <7 km/s, and a strong PmP arrival is observed at offsets 70-140 km for OBS 201 (Fig. DR5 and Fig. DR6). The slope of apparent arrivals changes for shots southwest of the Transition fault (Fig. DR5, offsets <-43 km, and Fig. DR6, offsets <-148 km).

**Tomographic Inversion**

The first step of our wide-angle data analysis was a tomographic inversion of all first arrival travel time picks using the same procedure as described in Christeson et al. (2008). We picked first arrival travel times for all OBS record sections, and then used the two-dimensional FAST tomographic inversion method (Zelt and Barton, 1998; Zelt et al., 1999) to invert for the velocity structure along the profile. The grid spacing of the velocity model was chosen as 100 m in both the horizontal and vertical directions for the forward calculation, and at 1 km in the horizontal
direction and 500 m in the vertical direction for the inverse grid. A smaller inverse grid spacing results in fine-scale lateral heterogeneities that cannot be adequately resolved with the experimental geometry and is not required to fit the data within the estimated uncertainties.

The starting model for the first tomographic inversion was a simple layered velocity model that fit the first arrivals at the nearest offsets. We used an iterative tomographic procedure with the final preferred model the iteration that produced the smoothest model with a chi-square value closest to 1.0 (i.e., the model fits the observed travel times within their independently estimated uncertainties). This preferred model was then smoothed below the seafloor and low-velocity zones were removed. These low-velocity zones are often an artifact of the starting model, and they do not allow adequate sampling of the model by source-receiver ray paths. The resulting velocity model was then used as the starting model for another iterative tomographic inversion. We next calculated travel times through the resulting velocity model and compared these with the observed travel times; this allowed us to remove travel time picks that are clearly outliers and to pick additional travel times at the further offsets where signal-to-noise ratios are lower. We repeated these steps several times to produce the final tomographic velocity model (Fig. DR7). The final inversion included ~15,500 travel time picks from 16 OBS receivers, with a RMS travel time residual of 91 ms and a chi-square value of 0.9.

**Interface Inversions**

The observed PmP arrivals differ greatly for OBS 217 located near the southwest end of the profile on Pacific crust (Fig. DR3) and OBS 201 located near the northeast end of the profile on Yakutat block crust (Fig. DR6). These observations are consistent with a change in Moho depth from Pacific crust to Yakutat block crust. The final tomographic velocity model (Fig. DR7) does display a change in deep structure (>10 km depth) near the Transition fault, with the 7.5 km/s
contour deepening by more than 10 km over a horizontal distance of only a few km. For an initial Moho model we carried out 2 inversions for an interface depth using the final tomographic velocity model and only PmP arrivals from 1) shots and receivers located southwest of the Transition fault, and 2) shots and receivers located northeast of the Transition fault. Average Moho interface depth is 11 km southwest of the Transition fault and 35 km northeast of the Transition fault (Fig. DR7).

**Finite Difference Models**

Our interface inversions constrain Moho depth for Pacific crust 10-90 km southwest of the Transition fault, and for Yakutat crust 40-115 km northeast of the Transition fault. The large change in Moho depth in the Transition fault region results in complicated arrivals, including energy that: 1) refracts through Pacific crust, Pacific mantle, and Yakutat crust (YAK Pg, Fig. DR3-DR4); 2) refracts through Pacific crust, Pacific mantle, Yakutat crust, and then reflects off Yakutat mantle (YAK PmP, Fig. DR3-DR4); 3) refracts through Pacific crust, Pacific mantle, Yakutat crust, and Yakutat mantle (YAK Pn, Fig. DR4); 4) refracts through Yakutat crust and Pacific mantle (PAC Pn, Fig. DR6). We used a 2-D acoustic finite-difference scheme (Kelly et al., 1976; Keiswetter et al., 1996) to model these arrivals and determine the Moho structure in our preferred velocity model displayed in Fig. 3 of the main text. Our starting velocity model was computed from the tomographic velocity model to a depth near the 6.5 km/s contour. We then varied Moho structure and deep crustal velocities, and chose as our preferred velocity model the one that produced arrivals that best matched the observed data.

Fig. DR3-DR6 display synthetic record sections for a Moho that deepens over a horizontal distance of 5 km (Fig. DR3b-DR6b) and 28 km (Fig. DR3c-DR6c). For OBS 217, the primary difference in the synthetics is the amplitude characteristics of the YAK Pg and YAK PmP
arrivals; the YAK Pg arrival is observed at a later offset and the YAK PmP at an earlier offset for the sharp Moho model (Fig. DR3b) compared to the gradual Moho model (Fig. DR3c). The observed YAK Pg and YAK PmP arrivals have an offset of $\sim$165 km and $\sim$155 km (Fig. DR3a), which better matches the sharp Moho model than the gradual Moho model. For OBS 213, neither model matches the observed data, which has a YAK Pg arrival that diminishes in amplitude at an offset of $\sim$105 km (Fig. DR4a). The sharp Moho model does have a lower amplitudes for the YAK Pg arrival, but the gradual Moho model has a less prominent YAK PmP that better matches the observed YAK PmP (Fig. DR4). OBS 208 displays a decrease in first arrival amplitudes at offsets of $\sim$60 km, and only a faint PAC Pn is observed (Fig. DR5a). These observed amplitudes are better matched by the sharp Moho model (Fig. DR5b) than the gradual Moho model (Fig. DR5c). The observed PAC Pn arrival for OBS 201 (Fig. DR6a) is stronger than observed for OBS 208 (Fig. DR5a). The primary difference in the synthetics is that the PAC Pn arrival has an onset of -155 km for the sharp Moho model and -140 km for the sharp Moho model; the observed data better matches the sharp Moho model. The labeled artifacts in the synthetic seismic records (Figure DR3b-DR6b) are the result of incomplete removal of reflections from the bottom of the velocity model. The finite-difference code contains a scheme to absorb plane waves that impinge on the model edges (Keiswetter et al., 1996), which is not sufficient to remove these artificial reflections.

Based on the comparison between synthetic and observed arrivals, we chose the sharp Moho model as our preferred velocity model. The Moho deepens from 11.5 km for Pacific crust to 31.5 km for Yakutat crust over a horizontal distance of 5 km; the Moho depths differ from the interface inversions because of slight changes to deep crustal velocities to better match amplitude characteristics of observed PmP arrivals. In particular, we tested models with differing velocities
at the base of the crust; a velocity of 7.2 km/s above the Moho provided a better fit than velocities of 6.8 km/s or 7.6 km/s. With our data we cannot resolve whether the Moho deepens over a horizontal distance <5 km, and it is possible that the Moho step is near-vertical.

REFERENCES CITED


FIGURE CAPTIONS

Figure DR1. Multi-channel seismic profile STEEP02 with a vertical exaggeration of approximately four at the seafloor. a) Uninterpreted. b) Interpreted. The crustal reflector and Transition fault are shown in black. Blue box shows the region displayed in Fig. DR2 (uninterpreted) and Fig. 2 of the main text (interpreted).

Figure DR2. Uninterpreted portion of seismic reflection profile STEEP02 near the Transition fault. Vertical exaggeration is ~10:1 at the seafloor. An interpreted version is displayed in Fig. 2 of the main text.

Figure DR3. a) Record section for STEEP02 shots recorded by vertical channel of OBS 217 located on Pacific crust. Data are plotted with a reduction velocity of 7 km/s, a bandpass filter with a lowpass of 3 Hz and a highpass of 15 Hz, and with a 1-s automatic gain control applied. b,c) Finite difference model for OBS 217 for the velocity model shown in inset.

Figure DR4. As for Figure DR3, except for the vertical channel of OBS 213 located on Pacific crust ~17 km southwest of the Transition fault.

Figure DR5. As for Figure DR3, except for the vertical channel of OBS 208 located ~43 km northeast of the Transition fault on Yakutat block crust.

Figure DR6. As for Figure DR3, except for the hydrophone channel of OBS 201 located in Yakutat Bay on Yakutat block crust.

Figure DR7. Final velocity model from tomographic inversion of STEEP02 first arrival travel time picks. Model is only shown where constrained by ray paths. White circles mark OBS positions, with labels indicating OBSs with record sections displayed in Figures S3-S6.
location of Transition Fault is indicated by the arrow. Yellow lines mark Moho depth from inversion using only Pacific crust receivers and PmP arrivals (model position 18-96 km) and Yakutat crust receivers and PmP arrivals (model position 145-222 km); Moho is only displayed where constrained by ray paths.
Figure DR1

Two-way travel time

NNESSW

12.5 km

Yakutat Crust

a) SSW

12.5 km

b) SSW

Pacific Crust

Transition Fault
Figure DR2
Figure DR5
Figure DR7