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Keywords

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Data report: crustal structure near IODP Expedition 345, Hess Deep Plutonic Crust¹

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Abstract

This report presents an analysis of ocean-bottom seismometer data to constrain crustal structure near Integrated Ocean Drilling Program (IODP) Expedition 345 (Hess Deep) Site U1415. Average crustal thickness is 5.0–5.5 km, which is less than the global average for oceanic crust; the decreased crustal thickness is accommodated by a thinner Layer 3 than the global average. Velocities at the top of Layer 3 of 5.9–6.1 km/s are slower than the global average of 6.33 km/s for young oceanic crust.

1. Introduction

Integrated Ocean Drilling Program (IODP) Expedition 345 (Hess Deep) Site U1415 recovered plutonic rocks (primarily olivine gabbro and troctolite) from oceanic crust formed at the fast-spreading East Pacific Rise (Expedition 345 Scientists, 2014). Low-resolution deep seismic reflection data indicate a crustal thickness of 5–5.5 km for oceanic crust north of the drill site (Zonenshain et al., 1980). This report presents an analysis of active-source ocean-bottom seismometer (OBS) data to provide improved constraints for crustal structure near Site U1415 (Figure F1).

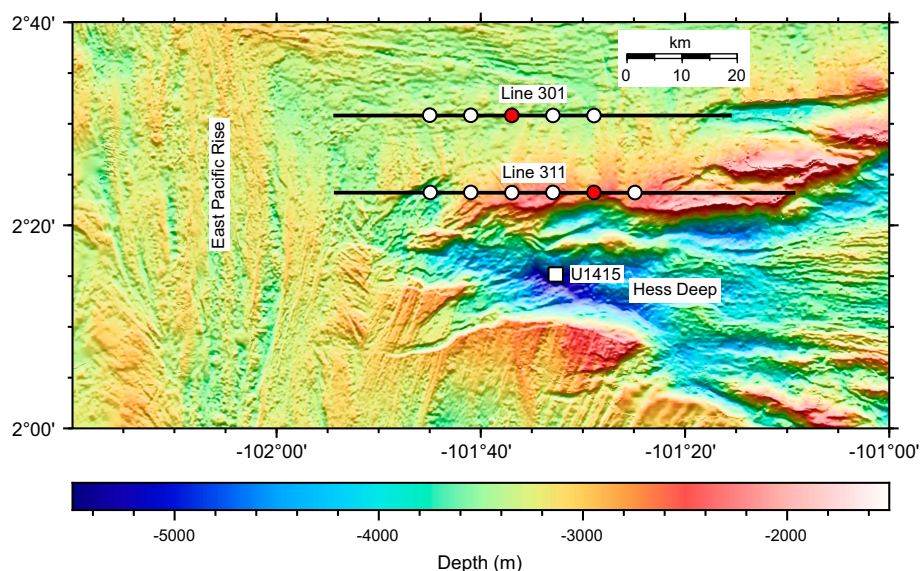


Figure F1. Location map of study region with topography from Ryan et al. (2009), Site U1415. Black lines = OBS profiles from Cruise EW0305, white circles = OBS instruments, red circles = instruments with record sections shown in Figure F2.

2. Methods and materials

Cruise EW0305 took place in 2003 on the research vessel (R/V) *Maurice Ewing*. Seismic Lines 301 and 311 (Figure F1) were acquired with a 20 air gun array sound source with a total volume of 3660 inch³. Shot spacing was 150 m for Line 301 and 200 m for Line 311. A total of 5–6 OBSs were positioned at 7.5 km spacing along each profile and recorded a hydrophone, vertical channel, and 2 horizontal channels. Two sample record sections are displayed in Figure F2.

Velocity models were obtained using a procedure similar to that of Christeson et al. (2020). For each profile, I constructed a 3 layer starting velocity model, with layers consisting of water, crust, and mantle with a 50 m grid spacing both horizontally and vertically. Water depths were obtained from multibeam bathymetric data, and the crust/mantle interface in the initial models was set at 5 km below the seafloor. Starting velocities in the crust increased from 2.7 km/s at the top of basement, 5.0 and 6.7 km/s at depths 0.5 and 2.5 km below the seafloor, respectively, and 7.2 km/s at the base of the crust. Mantle velocities were set at 8.0 km/s at the top of mantle and 8.1 km/s at the base of the model at a 15 km depth.

The following procedure was used to pick traveltimes and obtain a velocity model for each profile:

1. I calculated raypaths for crustal refractions (Pg), crust-mantle reflections (PmP), and mantle refractions (Pn) through the initial velocity models.
2. I picked Pg first arrivals, using the calculated Pg traveltimes for guidance, and carried out a tomographic inversion for the crustal velocity layer using the method of Van Avendonk et al. (2004).
3. I created a new initial velocity model with crustal velocities set at the average one-dimensional velocity-depth values from the tomographic inversion and calculated raypaths through this model.
4. I picked Pg, PmP, and Pn traveltimes using the calculated traveltimes for guidance. Uncertainties for Pg and Pn first arrivals were set to 20, 30, 40, and 50 ms for source-receiver offsets <20, 20–35, 35–50, and >50 km, respectively. Uncertainties were set to 50 ms for the PmP secondary arrivals. All picks were interpolated to an even spacing of 0.3 km.
5. I carried out a tomographic inversion for velocities in the crust and mantle layers and for the depth to the crust/mantle interface. Chi-squared misfit values in the final models are 1.0–1.1, indicating that the model fits the observations within uncertainties.

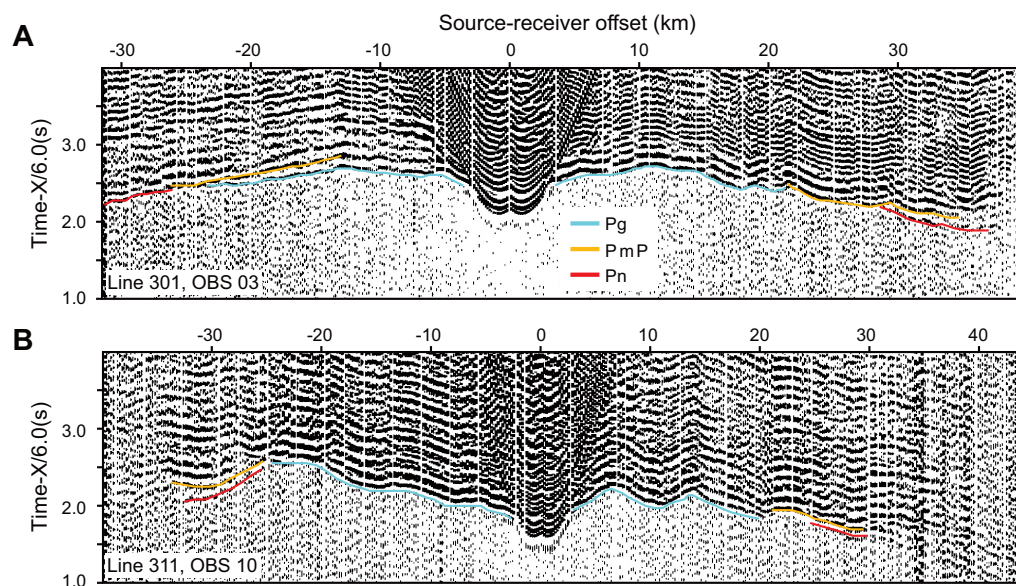


Figure F2. Record sections for vertical channel of OBSs 03 and 10 (Figure F1), Site U1415. Data are plotted with reduction velocity of 6 km/s with 0.5 s automatic gain control applied. Picked traveltimes are overlain.

3. Results

The final velocity models for Lines 301 and 311 show little along-profile variability (Figure F3). Average crustal thickness is 5.0 ± 0.3 km for Line 301 and 5.5 ± 0.4 km for Line 311. Resolution tests on similar data sets (Christeson et al., 2020) suggest that velocities in the upper and middle crust are well resolved for velocity anomalies with horizontal dimensions of 15 km and vertical dimensions of 1.5 km; the Mohorovicic discontinuity (Moho) interface has a depth resolution of 0.1–0.25 km. The gridded velocity models and seismic data are available at <https://www.marine-geo.org/tools/search/entry.php?id=EW0305>.

Figure F4 displays the average velocity-depth functions for Line 301 (Table T1) and Line 311 (Table T2) compared with the young (<7.5 Ma), fast/superfast (>40 mm/y half-spreading rate) subgroup from the oceanic crustal structure synthesis of Christeson et al. (2019). The average crustal thicknesses of 5.0 and 5.5 km (Lines 301 and 311, respectively) are less than the average thickness of 6.18 km for the young, fast/superfast subgroup. Oceanic crustal velocity models are often divided into two primary layers (e.g., Christeson et al., 2019), with velocities within the upper crust (Layer 2) increasing more rapidly with depth than the lower crust (Layer 3). The change in velocity gradient for the two profiles of this study is located at a ~1.5 km depth, with velocities at the top of Layer 3 averaging ~5.9 and 6.1 km/s (Lines 301 and 311, respectively) (Figure F4). A Layer 2 thickness of 1.5 km is similar to that of the young, fast/superfast subgroup of Christeson et al. (2019); the decrease in overall crustal thickness compared to that of average oceanic crust is accommodated by a thinner Layer 3 than the global average. Velocities at the top of Layer 3 of 5.9–6.1 km/s are slower than the global average of 6.33 km/s for young oceanic crust (Christeson et al., 2019).

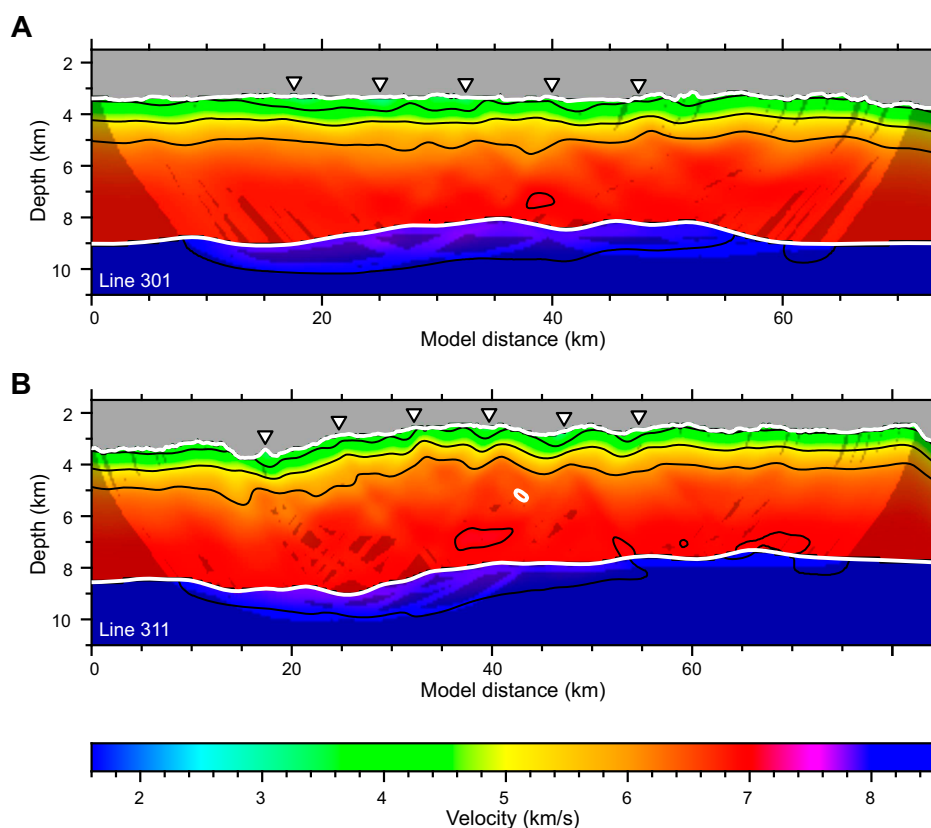


Figure F3. A, B. Tomographic inversion velocity models with lighter areas marking regions along each profile with ray coverage, Site U1415. Black lines = contour intervals of 1 km/s, white lines = water/seafloor and crust/mantle interfaces, inverted white triangles = OBS locations.

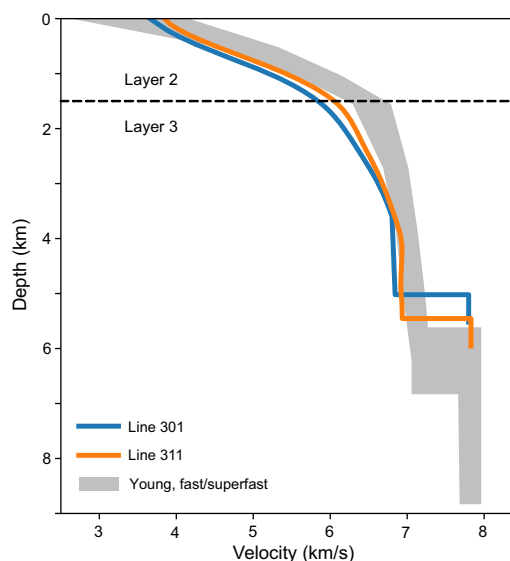


Figure F4. Average velocity-depth functions for Lines 301 and 311, Site U1415. Gray shaded region displays young (<7.5 Ma), fast (>40 mm/y half-spreading rate) subgroup from the oceanic crustal structure synthesis of Christeson et al. (2019).

Table T1. Average velocity-depth function for Line 301, Site U1415. [Download table in CSV format.](#)

Table T2. Average velocity-depth function for Line 311, Site U1415. [Download table in CSV format.](#)

4. Acknowledgments

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