
Data report: underway geophysics¹

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Introduction

Integrated Ocean Drilling Program Expedition 324 had long transits from Yokohama, Japan, to Shatsky Rise; between the five sites; and from Shatsky Rise to Townsville, Australia. In all, transits took approximately one-third of the entire time allotted for the expedition. Underway geophysical data were collected in international waters during transit and between drill sites. Bathymetry and magnetic data were collected using a 3.5 kHz CHIRP/echo-sounder and marine magnetometer, respectively (Fig. F1). A gyro-compass and a Global Positioning System (GPS) navigation system were used for positioning the bathymetric and magnetic data.

Methods

Navigation

The GPS navigation system was used throughout Expedition 324. A Trimble DSM232 GPS receiver was used as the primary navigation device. GPS positions were continuously updated at 1 s intervals and subsampled at 1 min intervals with a WINFROG software system. Subsequent processing and display of navigation data were performed using the Generic Mapping Tools software package (Wessel and Smith, 1995).

CHIRP/echo-sounder

A 3.5 kHz CHIRP/echo-sounder was used to acquire bathymetric data as well as high-resolution subbottom seismic reflection data. The 3.5 kHz system uses a SyQwest Bathy-2010 echo-sounder system driven by a single EDO-type 323c transducer. The transducer is mounted in a sonar dome located 45.5 m forward of the ship's moonpool. Digital bathymetry and Society of Exploration Geophysicists (file format "Y") subbottom seismic data were recorded on the SyQwest Bathy-2010 echo-sounder system during all transits.

Marine magnetometer

Total intensity measurements of the Earth's magnetic field were obtained with a Geometrics Model G-886 proton precession marine magnetometer towed ~300 m astern. Magnetic data were recorded at 3 s intervals and then reduced to 1 min intervals with

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navigation data produced by the WINFROG navigation software. In order to measure the effect of the ship's magnetic field with heading, a circular survey (~7 km in diameter) was conducted while in transit from Site U1349 to Site U1350 between Universal Time Coordinated (UTC) 1055 h and 1215 h on 12 October 2009 (Fig. F2). This method was proposed by Bullard and Mason (1961). The equation for predicting the effect of the ship's magnetic field is:

$$F_Q = F + C_0 + C_1 \cos\theta + C_2 \cos 2\theta + S_1 \sin\theta + S_2 \sin 2\theta,$$

where θ is the ship's heading measured clockwise from north, F_Q is the total field at location Q , F is the ambient magnetic field, and C_0 , C_1 , C_2 , S_1 , and S_2 are constants dependent on the ship's magnetic properties (Bullard and Mason, 1961). For a symmetrical ship, the sine terms are negligible compared with the cosine terms; therefore, we set S_1 and S_2 to 0. To minimize diurnal effects, the survey calibration circle was conducted at night (time difference between local time and UTC is +10 h). The circular survey was conducted over a relatively flat portion of seafloor (depth variation between 3242 and 3342 m) (Fig. F3). Even though the International Geomagnetic Reference Field (IGRF) values around the circular survey show only 40 nT differences (from 41,851 to 41,950 nT), the maximum differences observed are as much as 100 nT (from 41,723 to 41,823 nT). The measured magnetic data were plotted versus magnetic heading, and a best fit curve was computed (Fig. F4). The computed heading correction constants C_0 , C_1 , and C_2 of the R/V *JOIDES Resolution* from 300 m astern are

$$C_0 = 48.16,$$

$$C_1 = -52.61, \text{ and}$$

$$C_2 = 4.45.$$

Thus, the magnetic field errors generated by the ship (F_H) are expressed as

$$F_H = 48.16 - 52.61 \cos\theta + 4.45 \cos 2\theta.$$

The obtained constants C_0 and C_1 are higher than previously reported results ($C_0 = -3.2$ to 5.5 ; $C_1 = -12.9$ to -3.0) measured from other research vessels (Bullard and Mason, 1961; Buchanan et al., 1996). Higher constants are expected because of the length of the *JOIDES Resolution* compared to the lengths of other research ships. Even though the magnetometer was towed 300 m astern, this distance is not sufficient to avoid the ship's magnetic effect. The acquired total fields were reduced to magnetic anoma-

lies using the 10th generation IGRF coefficients (McLean et al., 2004; Maus et al., 2005). Before correction of the ship's heading effect, the maximum track crossover errors are as much as 48 nT (root mean square [RMS] = 20 nT) at track crossings. After the ship's heading effect was corrected, the crossovers are reduced to 13 nT (RMS = 9 nT). Herein, we provide the results from both before and after the ship's heading correction.

Results

During Expedition 324, bathymetry data and marine magnetic data were collected for 8559 km (Fig. F5). The transits of the expedition were divided into six legs and named sequentially (Transits EXP324-L1T–EXP324-L6T) for convenient identification of each transit (Table T1).

Bathymetry

Shatsky Rise contains three large volcanic massifs (Tamu, Ori, and Shirshov), and the flanks of these massifs typically have gentle slopes of ~1.5° (Sager et al., 1999) (Fig. F6). During the first transit (EXP324-L1T) from Yokohama to Site U1346, the ship passed over the Japan Trench, a deep abyssal plain, and the northern flank of the Ori Massif and ended at the summit of Shirshov Massif (Figs. F6, F7). The deepest part of the Japan Trench is deeper than 7000 meters below sea level (mbsl), with a ~2.6° slope angle, whereas the water depth of the abyssal plain ranges from 5900 to 5600 mbsl, except over a seamount (36°48.7970'N, 154°04.8012'E), which shallows up to 5200 mbsl. The northern flank of the Ori Massif has a gentle surface with some high peaks and shallows toward the Shirshov Massif. The seafloor bathymetry between Sites U1346 and U1347 (Transit EXP324-L2T) is characterized by several seamounts that shoal to between 3900 and 3500 mbsl, jutting from a flat plain at ~5000 mbsl ("Sliter Basin") (Fig. F8). The third transit (EXP324-L3T), from Sites U1347 to U1348, crossed the northeast flank of Tamu Massif, where water depth varies between 3000 and 3500 mbsl (Fig. F9). Bathymetry data were collected over the summit of "Cooperation Seamount" while in transit between Sites U1348 and U1349 (Transit EXP324-L4T). The seamount has a steep flank and twin peaks with the shallowest depth at 2700 mbsl, as reported by Sager et al. (1999) (Fig. F10). The summit of Ori Massif is flat, and the flanks have a gentle slope angle of ~1.2° on Transit EXP324-L5T (Fig. F11). After drilling at Site U1350, the ship moved to the southwest to pass over a high feature (4400 m) within Helios Basin (Transit EXP324-L6T). The ship then turned to the south over the western summit of

Tamu Massif (Fig. F12A). The summit has a broad, dome-shaped feature, and the southern flank of the massif has a $\sim 2^\circ$ slope toward the south. The depth of the ocean floor surrounding the Shatsky Rise is deeper than 5500 mbsl, and some sea knolls rise a few hundred meters from the floor. The ship continued to move toward the south and crossed the Marcus-Wake and Magellan seamount chains, which developed around the Jurassic Quiet Zone (Fig. F5). The Marcus-Wake Seamounts show a west–northwest trend, and numerous seamounts are scattered over ~ 400 km. Most of them have pointed peaks, but some have flat tops (guyots) (Fig. F12B). Likewise, the Magellan Seamounts show a trend of north–northwest to south–southeast, and seamounts rise above the surrounding ocean floor at ~ 6000 mbsl. The ship passed through the Caroline Islands located on the southern margin of the Mariana Basin and over the western flank of Ontong Java Plateau, where water depth ranges from 4000 to 2000 mbsl (Figs. F5, F12C). Between the Ontong Java Plateau and the Solomon Islands, the Kilinailau Trench lies with an ~ 30 km width. The Solomon Island arc is separated from Solomon Basin by the New Britain Trench, the deepest point of which reaches below 7500 mbsl. Bathymetry of Solomon Basin generally shoals to the south up to 4000 mbsl. Another deep submarine basin, Woodlark Basin, is located between Woodlark and Pocklington ridges.

Magnetic anomalies

Magnetic anomalies over the abyssal plain west of Shatsky Rise vary from -250 to 250 nT and show mostly positive anomalies except in a location over a seamount (Fig. F7). However, near the northern part of Ori Massif, the magnetic anomalies are again negative with low values of about -380 nT. The summit of Shirshov Massif shows anomalies of -50 to 100 nT, and between the southwestern flank of the Shirshov Massif and the northern flank of Tamu Massif, anomalies vary from -250 to 250 nT (Fig. F8). At the northern flank margin of Tamu Massif, anomalies fluctuate highly (between -400 and 400 nT) and show mainly positive values toward the western slope of the massif (Site U1347). Magnetic anomalies in transit from Site U1347 to Site U1348 show positive values up to 250 nT (Fig. F9). In the confines of Helios Basin, magnetic data show high positive anomalies up to 450 nT, whereas over Cooperation Seamount, magnetic data show weakly negative anomalies (Fig. F10). On the summit of Ori Massif, magnetic anomalies vary between -150 and 150 nT (Fig. F11). Anomalies between Ori and Tamu massifs fluctuate from -250 to 250 nT, but show mainly positive anomalies in the summit area of Tamu Massif

(Fig. F12A). On the southern slope of Tamu Massif, magnetic anomalies show a deep trough of -300 nT and fluctuate with mostly positive values toward the abyssal plain where the Hawaiian magnetic lineations are developed (Fig. F12A). However, from ~ 1100 km along the transit from Site U1350 to Townsville over the Hawaiian lineations, magnetic anomalies have very low amplitudes, except in the regions of seamounts (Marcus-Wake and Magellan seamount chains) (Fig. F12A, F12B). The area where magnetic anomalies show low-amplitude features in the western part of the mid-Pacific plate is known as the Jurassic Quiet Zone (Tominaga et al., 2008) (Fig. F5). These low-amplitude anomalies continued southward to the Caroline Islands north of the Ontong Java Plateau. At the Caroline Islands, magnetic data show an anomalous high peak up to 800 nT, whereas in the vicinity of the western flank of Ontong Java Plateau, magnetic anomalies vary between -150 and 150 nT (Fig. F12C). Deep troughs of negative magnetic anomalies less than -350 nT are shown in the southwestern margin of Ontong Java Plateau near the Kilinailau Trench and the Solomon Island arc. Magnetic anomalies in the Solomon and Woodlark basins also show mostly negative values, but some high peaks of positive anomalies (~ 250 nT) are observed around the Pocklington Ridge (Fig. F12C).

Acknowledgments

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Figure F1. Illustration of underway geophysical data acquisition during Expedition 324.

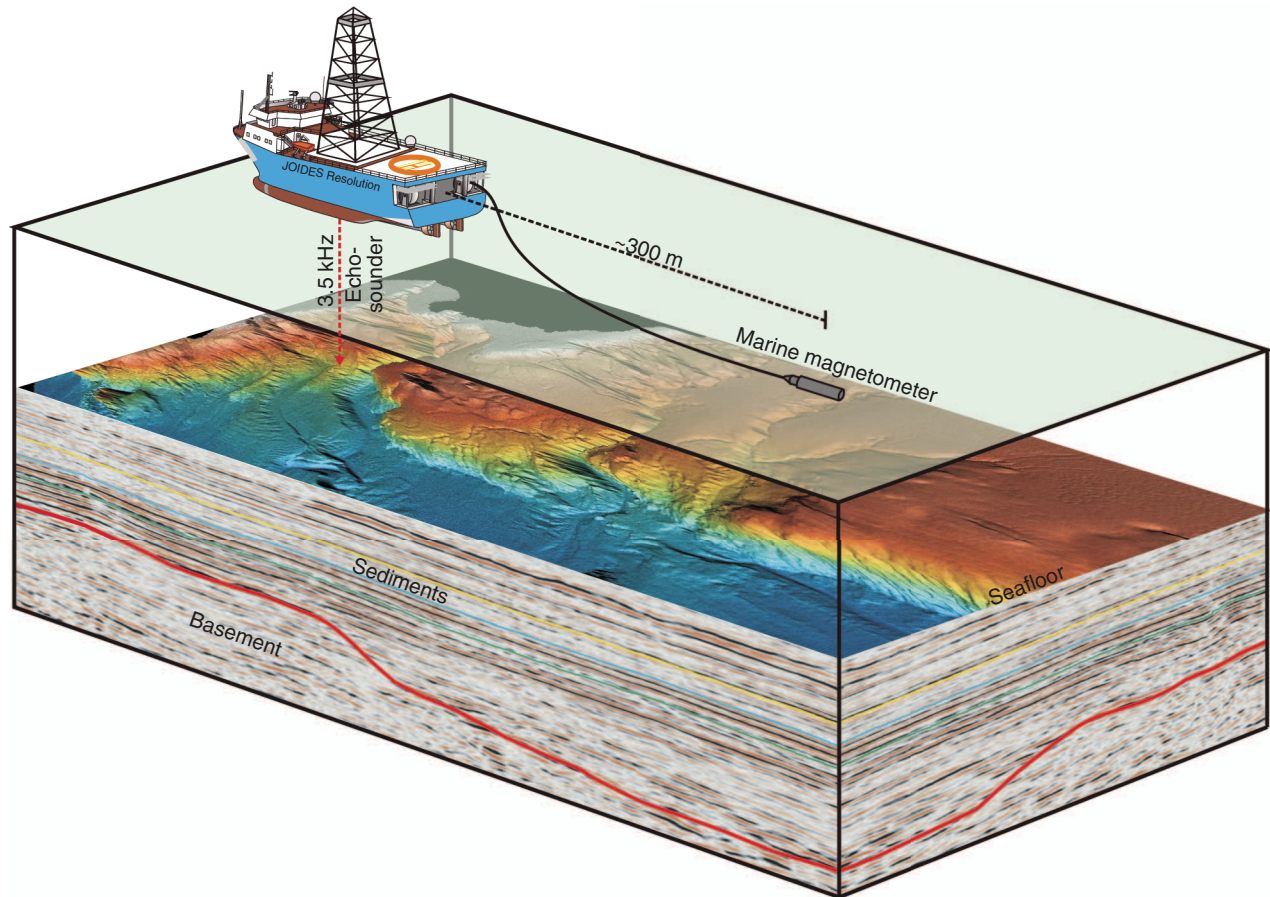


Figure F2. Track line of clockwise circular survey for ship’s magnetic heading correction conducted in transit from Site U1349 to U1350. Annotations are time in Universal Time Coordinated. Red dots along track are at 10 min intervals. Contours and colors indicate bathymetric depths using the 30 arc-s resolution GEBCO_08 grid (General Bathymetric Chart of the Oceans, 2008).

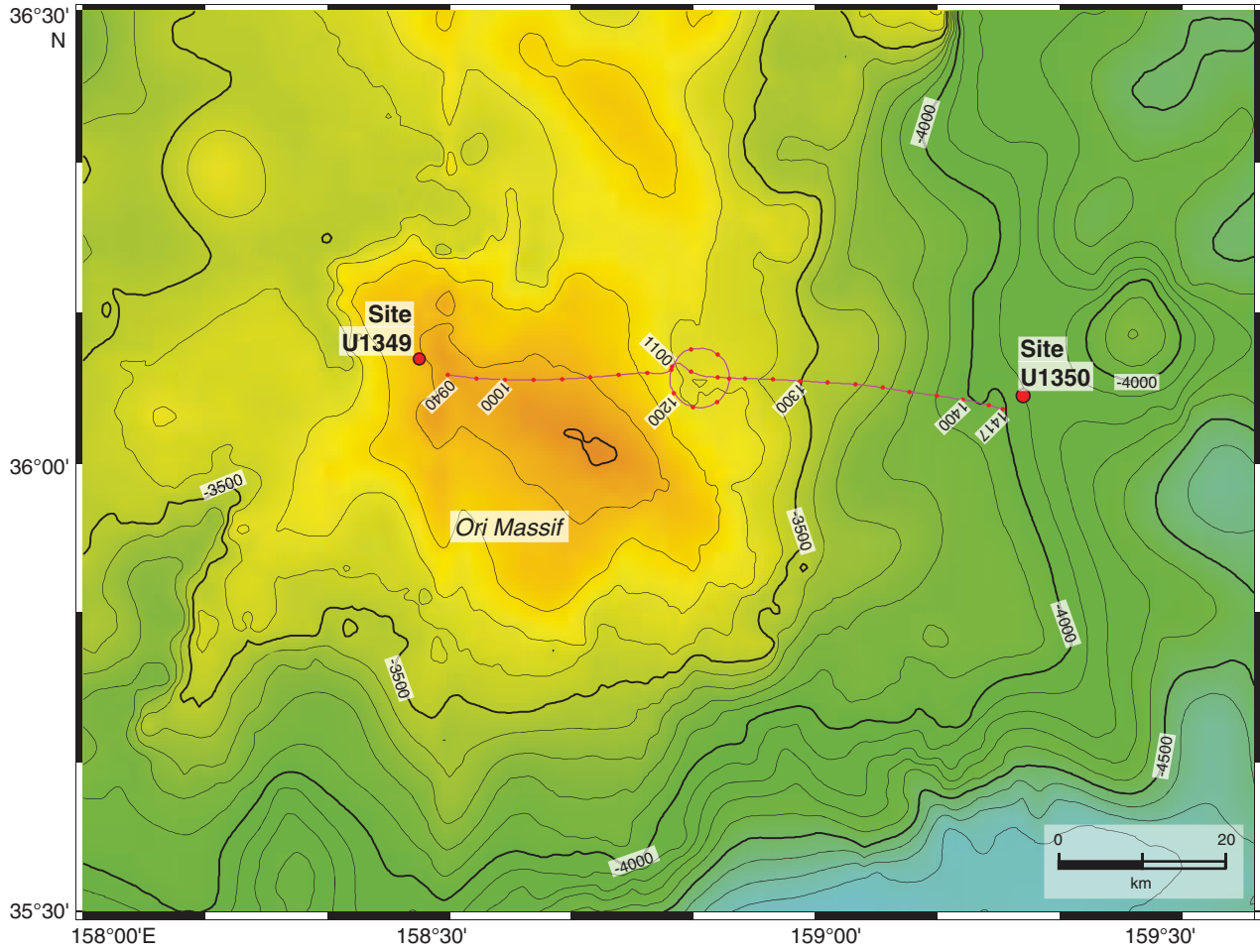


Figure F3. Profiles of International Geomagnetic Reference Field (IGRF), total magnetic field, magnetic anomaly, and bathymetry of the circular survey. Time is Greenwich Mean Time.

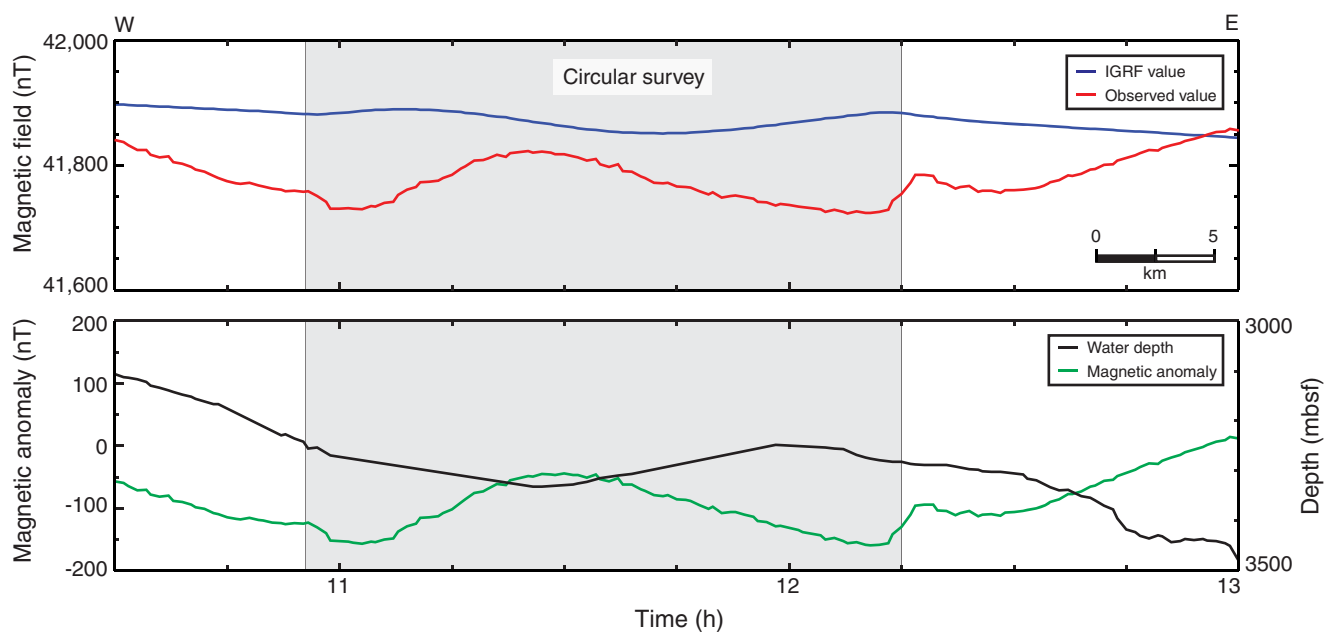


Figure F4. Plot of variation of measured field with ship's heading. Solid red line is computed best fit curve to the measured magnetic field (blue circles) using the formula of Bullard and Mason (1961).

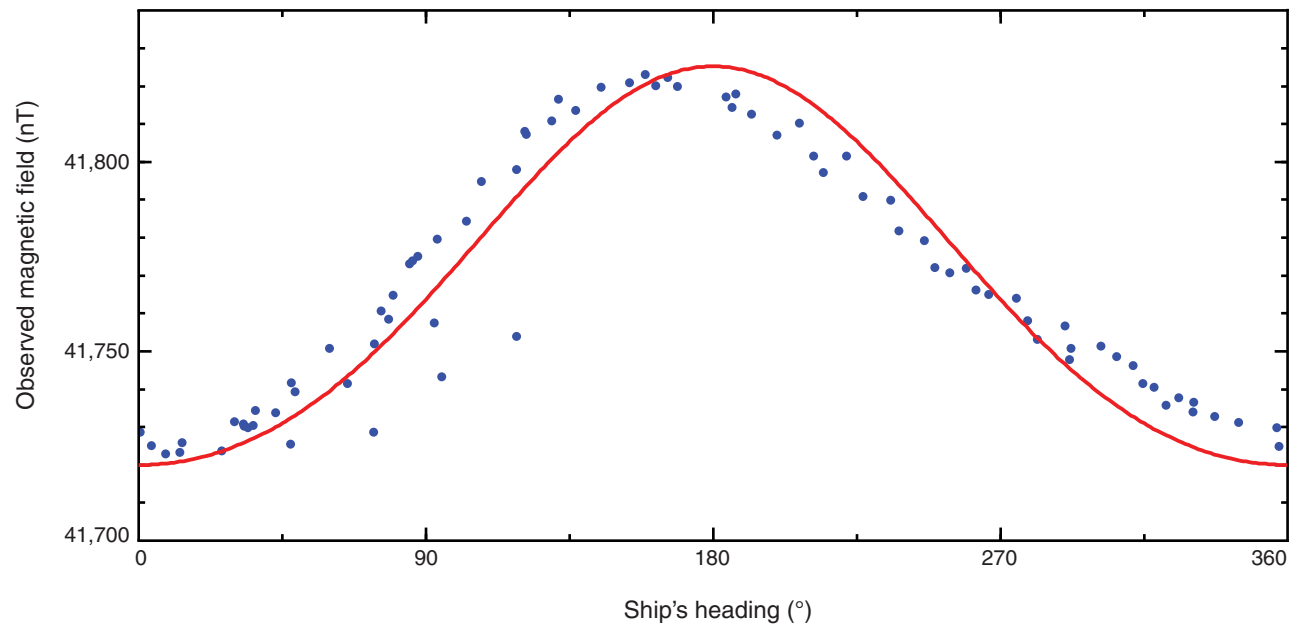


Figure F5. Geophysical track lines collected during Expedition 324. Topography was made using the 30 arc-resolution GEBCO_08 grid (General Bathymetric Chart of the Oceans, 2008). Red circles = Expedition 324 drill sites, yellow dashed lines = Hawaiian and Japanese magnetic lineations (Nakanishi et al., 1999). CAR = Caroline Islands, HML = Hawaiian magnetic lineations, JQZ = Jurassic Quiet Zone, JML = Japanese magnetic lineations, MB = Mariana Basin, MS = Magellan Seamounts, MWS = Marcus-Wake Seamounts, PR = Pocklington Ridge, SB = Solomon Basin, SIA = Solomon Islands arc, WR = Woodlark Ridge.

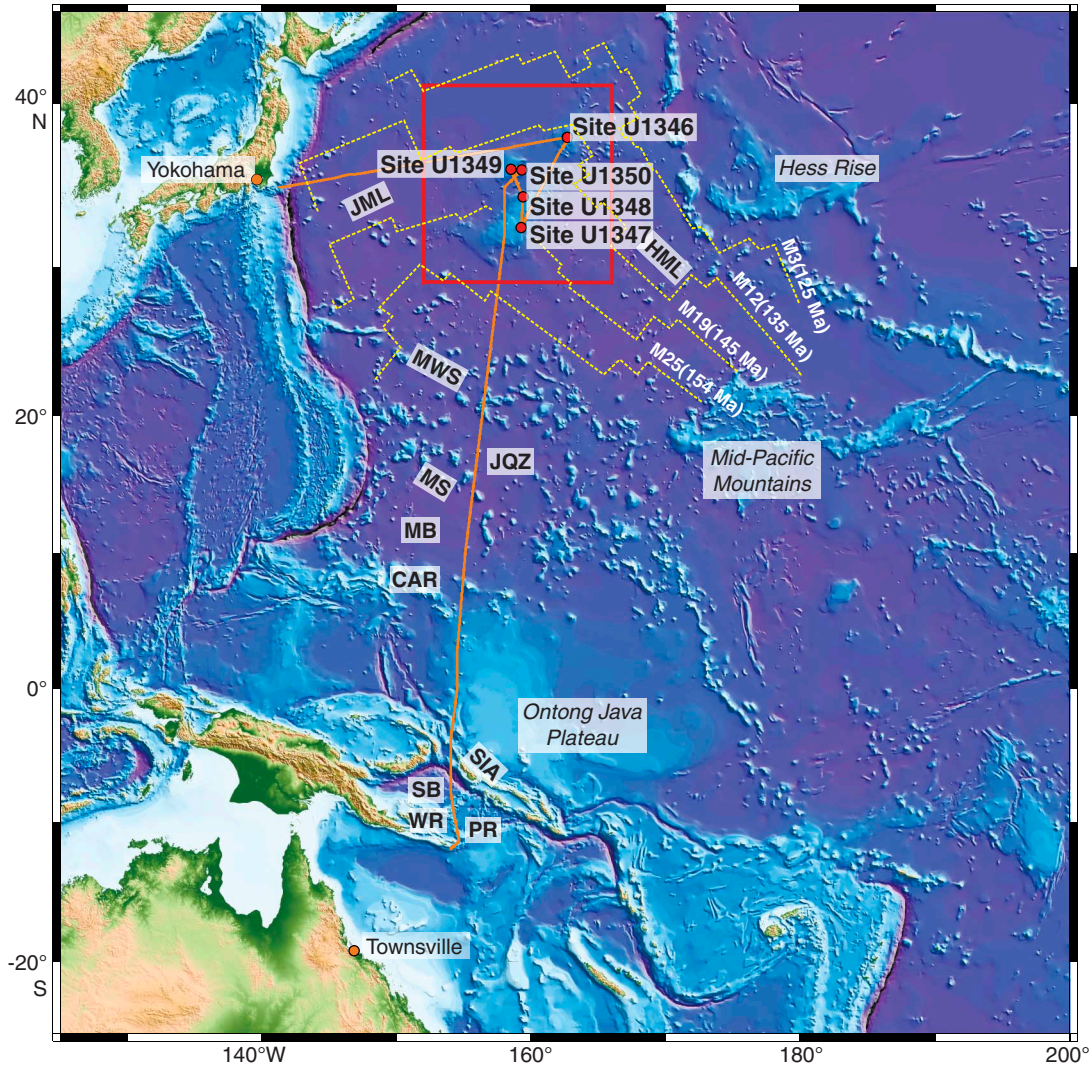


Figure F6. Bathymetric map of the Shatsky Rise using the 30 arc-s resolution GEBCO_08 grid (General Bathymetric Chart of the Oceans, 2008). Solid lines = ship tracks during transits, red circles Expedition 324 drill sites. L1T = Transit EXP324-L1T (Fig. F7), L2T = Transit EXP324-L2T (Fig. F8), L3T = Transit EXP324-L3T (Fig. F9), L4T = Transit EXP324-L4T (Fig. F10), L5T = Transit EXP324-L5T (Fig. F11), L6T = Transit EXP324-L6T (Fig. F12).

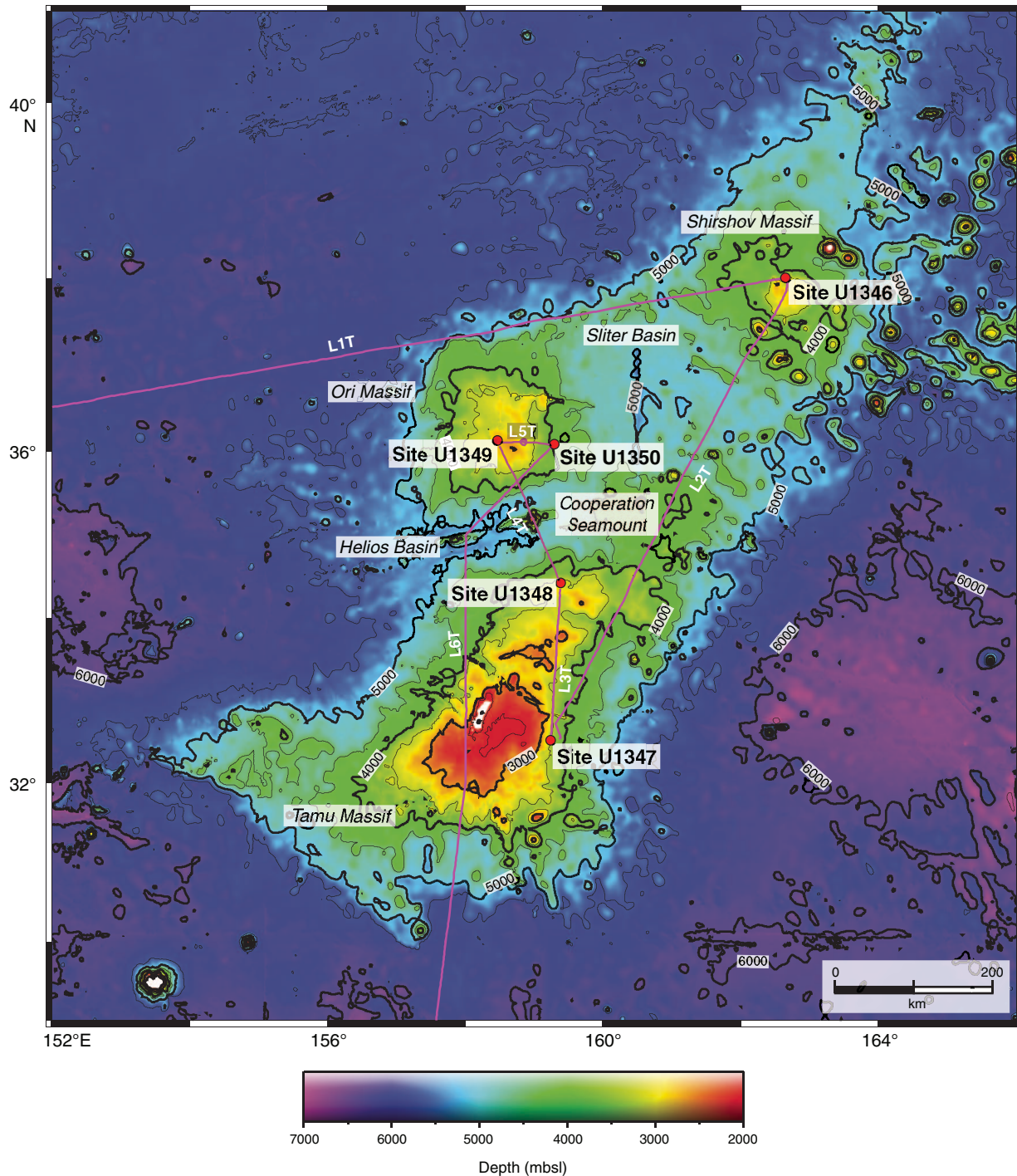


Figure F7. Magnetic anomaly, bathymetry, and CHIRP profiles of Transit EXP324-L1T from Yokohama, Japan, to Site U1346. See Figures F5 and F6 for location.

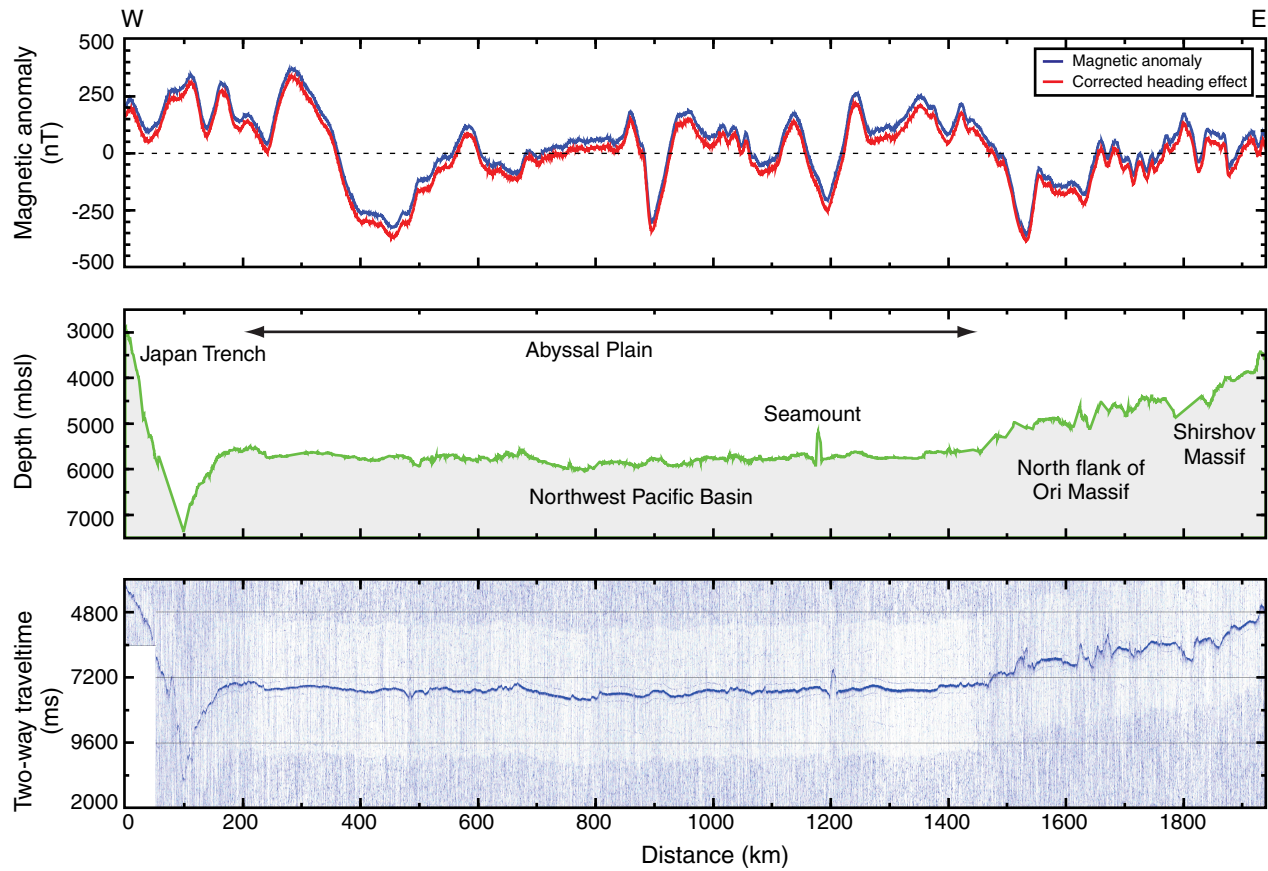


Figure F8. Magnetic anomaly, bathymetry, and CHIRP profiles of Transit EXP324-L2T from Site U1346 to U1347. See Figure F6 for location.

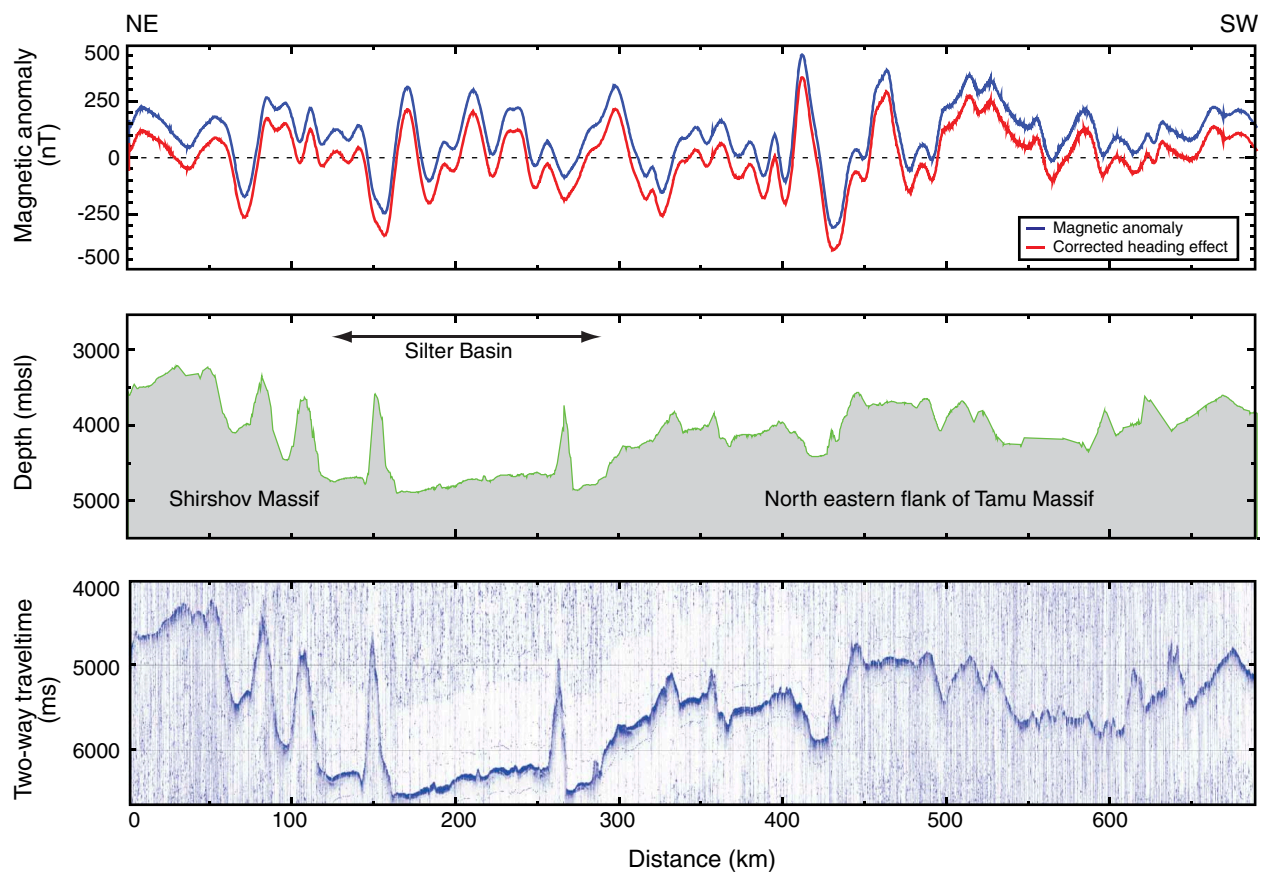


Figure F9. Magnetic anomaly, bathymetry, and CHIRP profiles of Transit EXP324-L3T from Site U1347 to U1348. See Figure F6 for location. Magnetic anomaly line is concealed by corrected heading effect line.

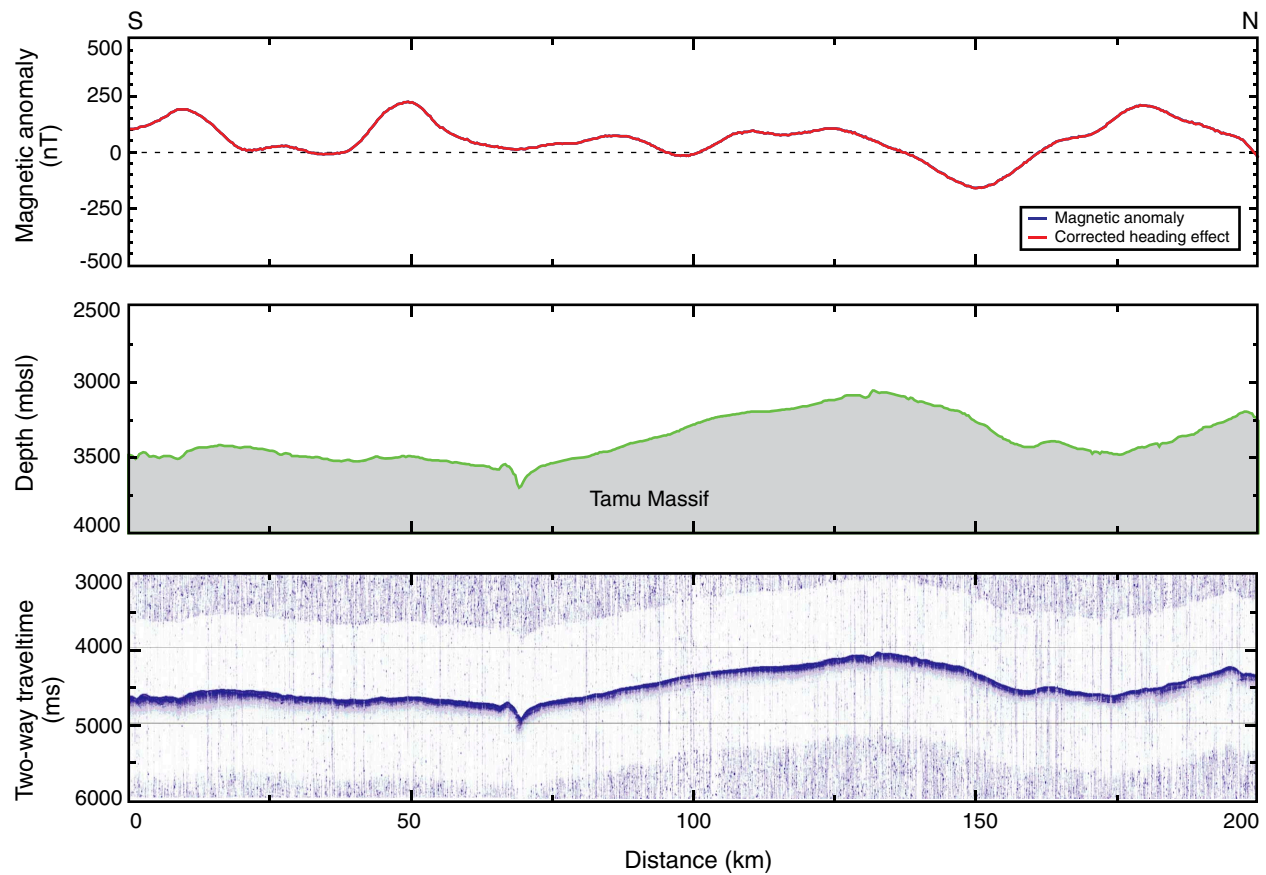


Figure F10. Magnetic anomaly, bathymetry, and CHIRP profiles of Transit EXP324-L4T from Site U1348 to U1349. See Figure F6 for location. Magnetic anomaly line is concealed by corrected heading effect line.

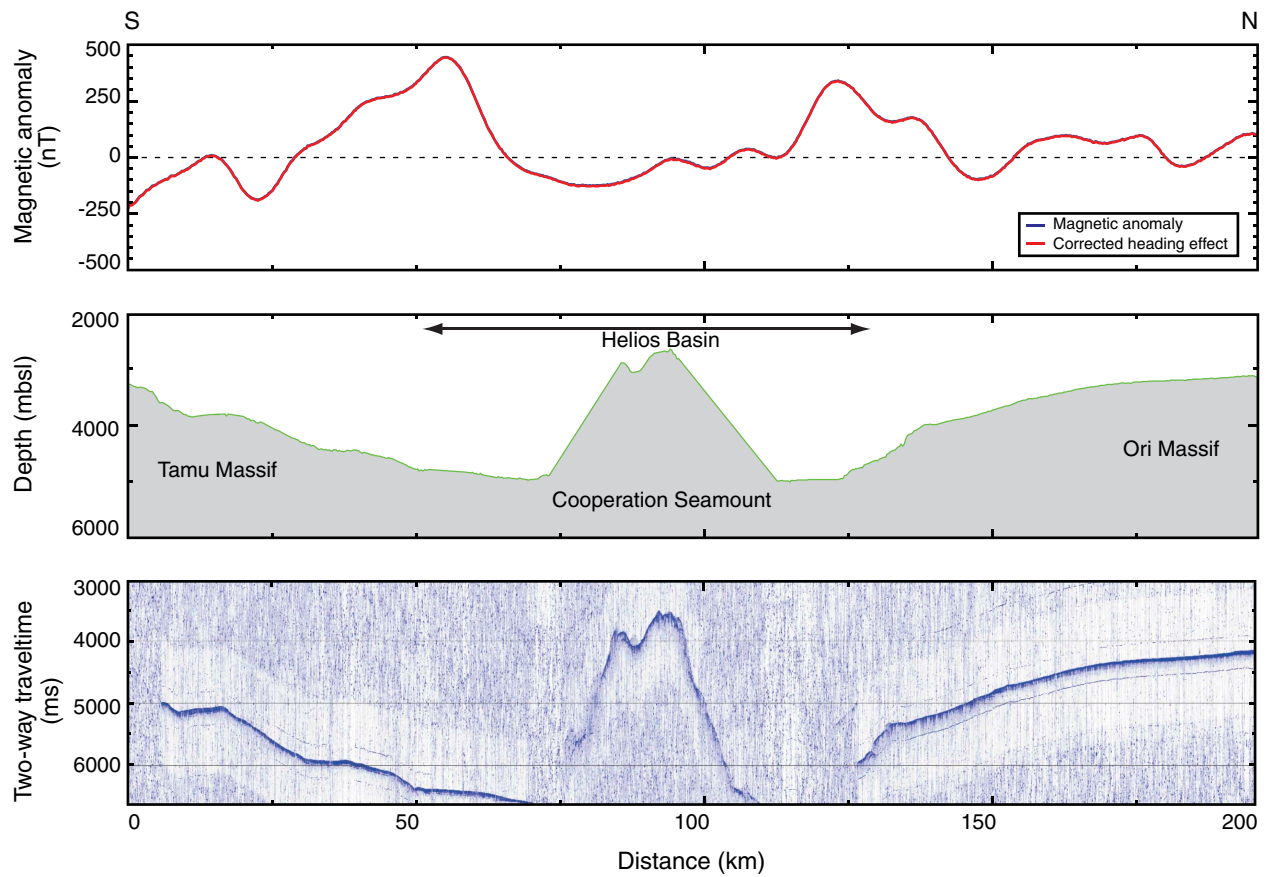


Figure F11. Magnetic anomaly, bathymetry, and CHIRP profiles of Transit EXP324-L5T from Site U1349 to U1350. See Figure F6 for location.

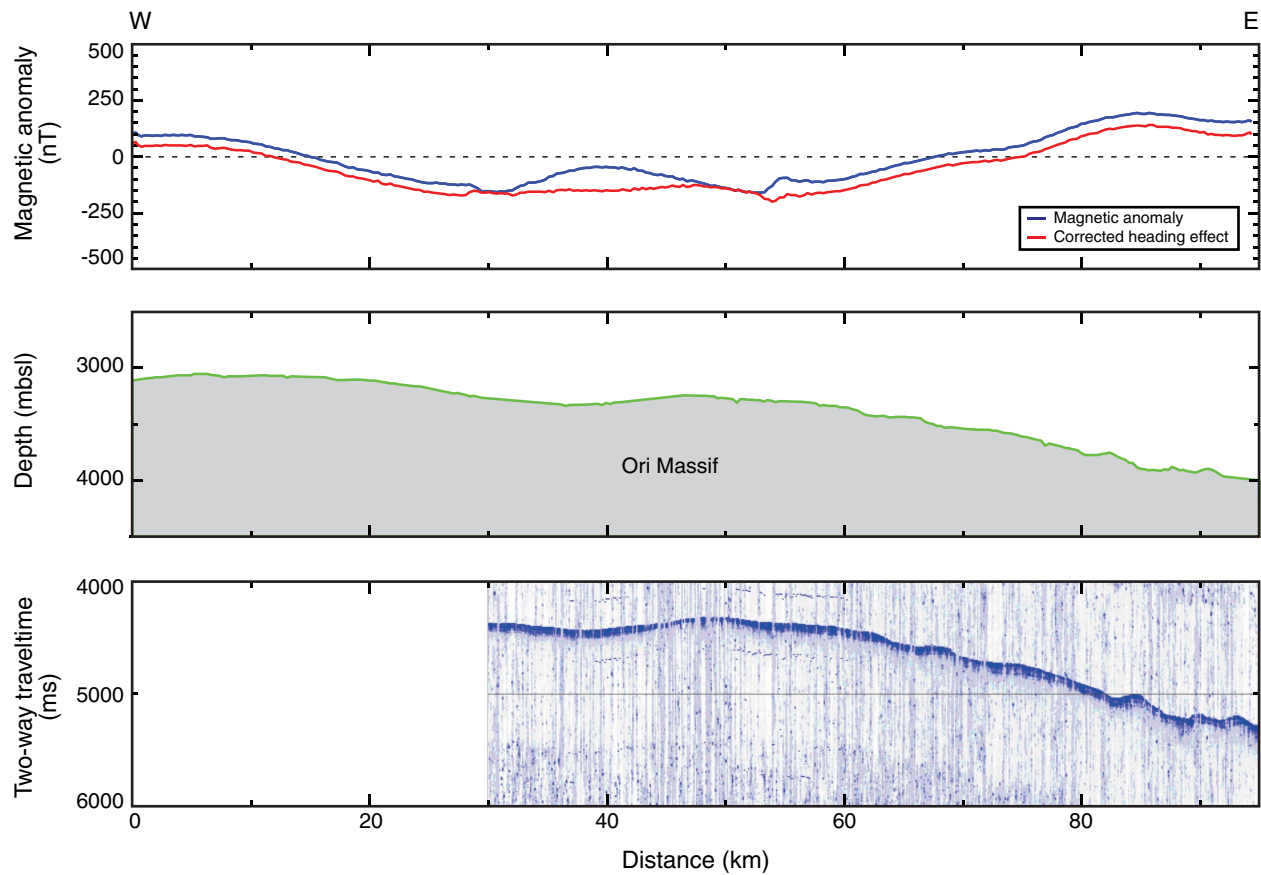


Figure F12. Magnetic anomaly, bathymetry, and CHIRP profiles of Transit EXP324-L6T. See Figures F5 and F6 for location. A. Site U1350 to latitude 25°N. (Continued on next two pages.)

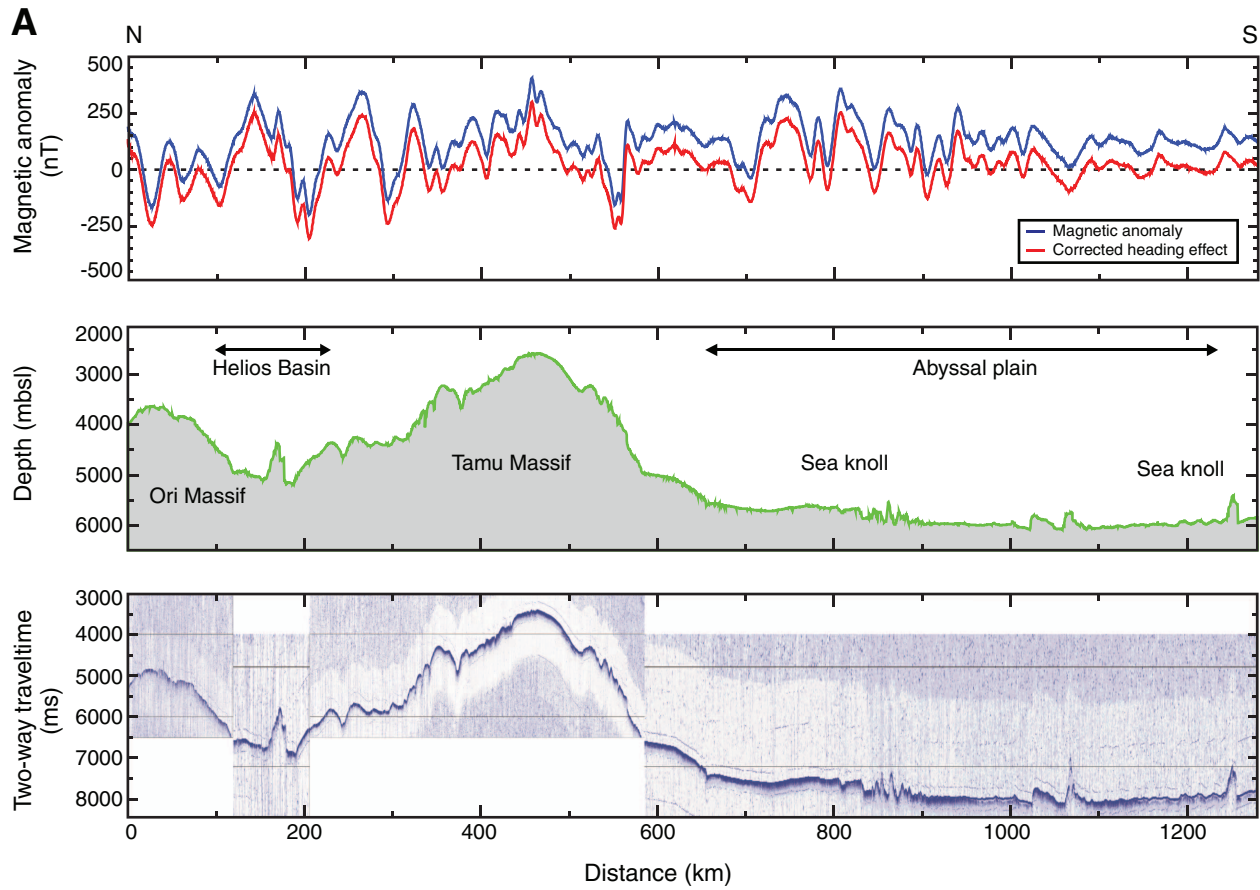


Figure F12 (continued). B. Latitude 25°–10°N. (Continued on next page.)

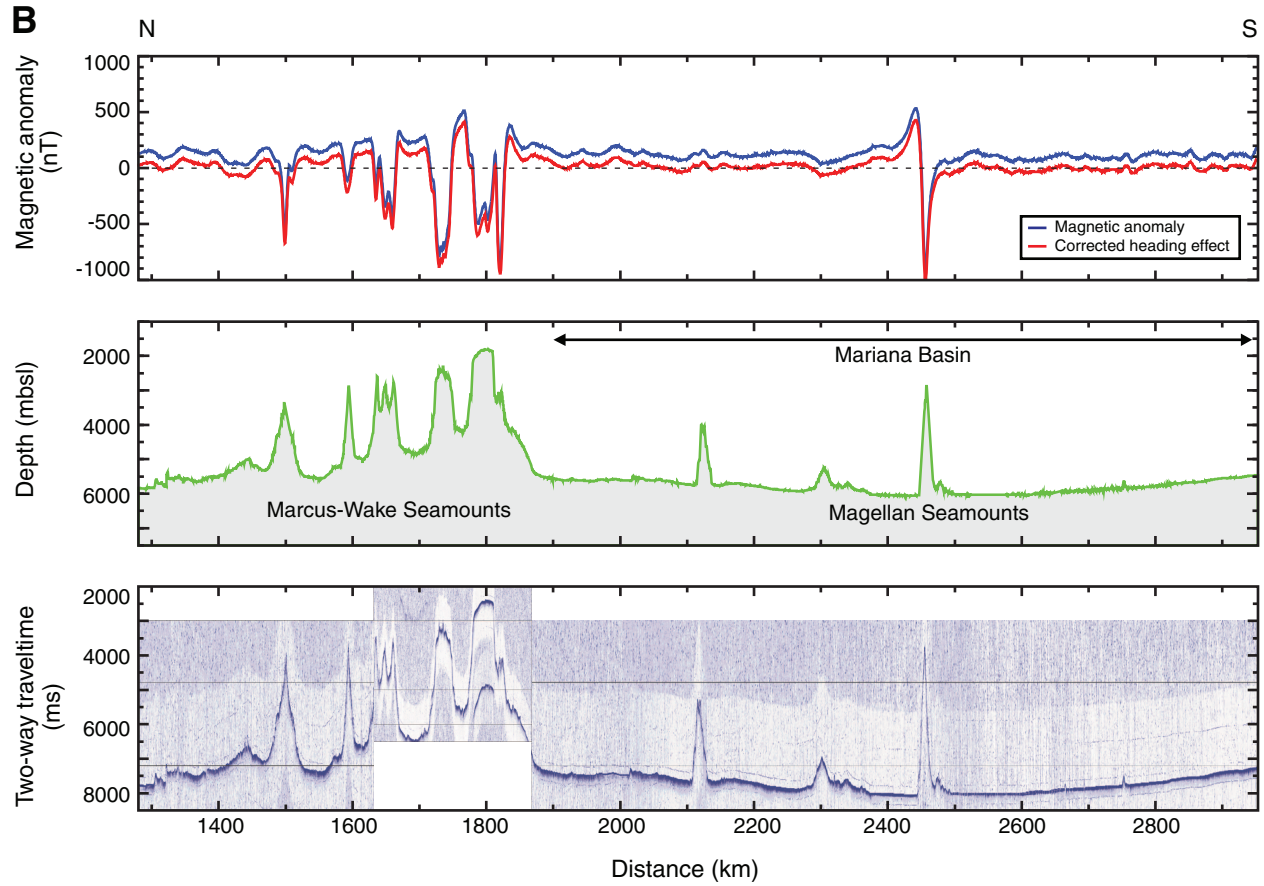


Figure F12 (continued). C. Latitude 10°N–12°S. Green dashed line = Equator. WR = Woodlark Ridge, PR = Pocklington Ridge.

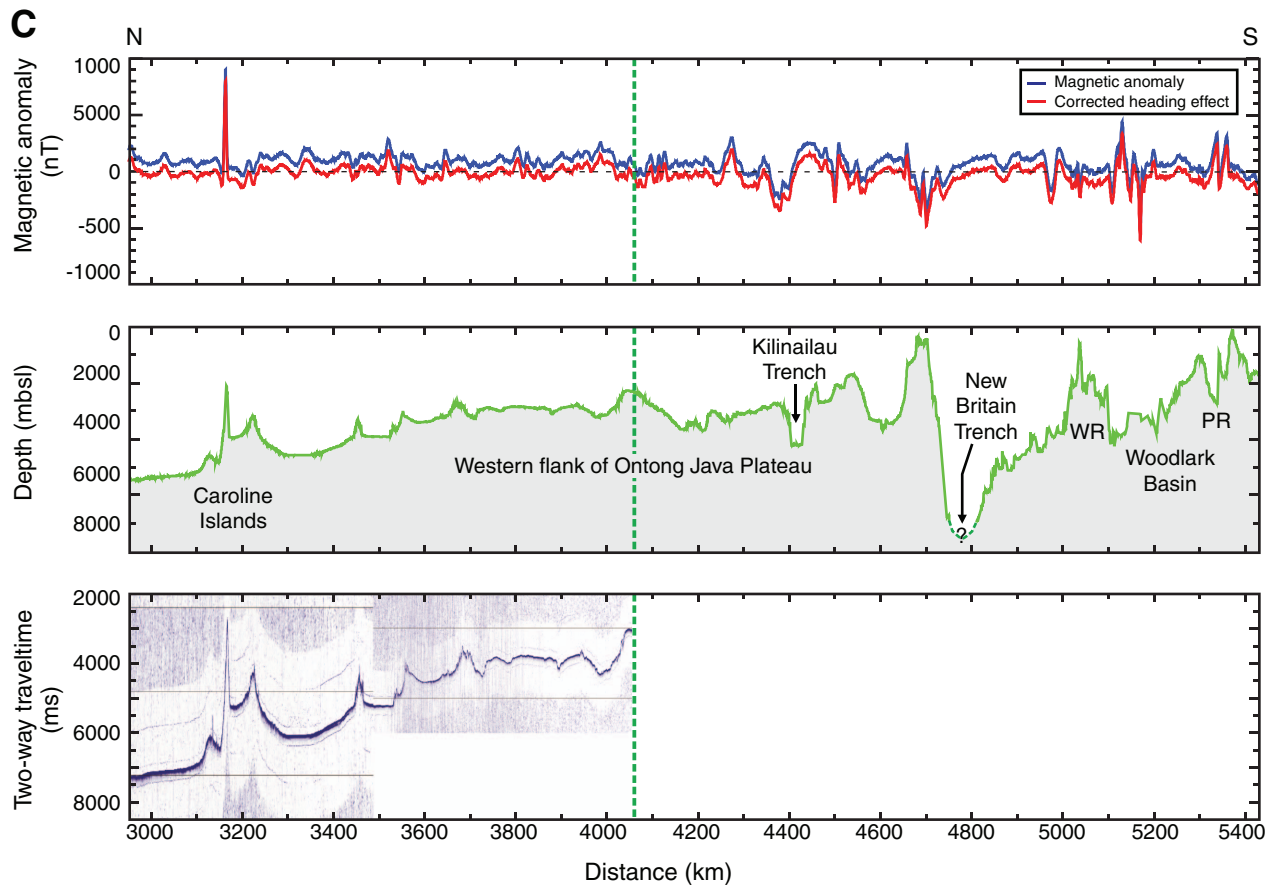


Table T1. Transit segments information for Expedition 324.

Transit	From	To	Distance (km)
EXP324-L1T	Yokohama, Japan	Site U1346	1943
EXP324-L2T	Site U1346	Site U1347	693
EXP324-L3T	Site U1347	Site U1348	203
EXP324-L4T	Site U1348	Site U1349	196
EXP324-L5T	Site U1349	Site U1350	94
EXP324-L6T	Site U1350	Townsville, Australia	5430