Underway geophysics[1]

L.M. Kalnins[2] and the Expedition 330 Scientists[2]

Chapter contents

Introduction

Integrated Ocean Drilling Program (IODP) Expedition 330 to the Louisville Seamount Trail had long transits of ~1500 km from Auckland, New Zealand, to the first drill site on Canopus Guyot and from the last drill site on Hadar Guyot to Auckland, New Zealand, as well as substantial transits between sites (Figs. F1, F2). In total, more than 4600 km of underway geophysical data were collected during the expedition. Bathymetric and magnetic data were collected using a 3.5 kHz echo sounder and a towed marine magnetometer, respectively, and positioned using a gyrocompass and GPS navigation system.

Methods

Navigation

The GPS navigation system and gyrocompass were used for the duration of Expedition 330. The R/V *JOIDES Resolution* is equipped with two Ashtech GG24 GPS+GLONASS receivers with antennas and a Scandinavian Micro Systems LR40DC Digital Gyro Repeater. GPS position was continually updated at 1 s intervals, and integrated navigational software subsampled these data to align with bathymetric and magnetic sampling intervals. Loss of GPS information during Expedition 330 was rare, generally affecting no more than a few consecutive data points, with the exception of ~100 km during Transit L7T, where no positioning data were available for the magnetic anomaly data.

Bathymetry

A SyQwest Bathy 2010 CHIRP Subbottom Profiler and Bathymetric Echo Sounder system were used to acquire bathymetric data as well as high-resolution subbottom seismic reflection data. The SyQwest Bathy 2010 system consists of a 3.5 kHz transducer array using 12 TR-109 transducers driven by a 10 kW power amplifier and mounted in a sonar dome 45.5 m forward of the moonpool on the *JOIDES Resolution*. Bathymetric and seismic data were recorded for all transits except Transit L5T.

After collection, the bathymetric data were filtered to remove individual bad depth readings or small clusters of unreliable depths. This filtering was based on the fourth derivative of the data, which is very sensitive to the very narrow, sharp spikes characteristic of a

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doi:10.2204/iodp.proc.330.109.2012
[2]Expedition 330 Scientists' addresses.
Correspondence author:
lara.kalnins@earth.ox.ac.uk

few isolated unreliable data points. Two filtering passes were done, each removing data points with a fourth derivative value of >1000 m/(sample distance)^4. The data were then projected onto the great circle that best fit the transit path and aligned with the magnetic anomaly data for plotting.

Magnetic anomaly

Total intensity measurements of the Earth's magnetic field were collected using a Marine Magnetics SeaSPY Overhauser magnetometer towed ~500 m astern. The SeaSPY magnetometer has an accuracy of 0.1 nT, with a repeatability of 0.01 nT. Kang et al. (2010) investigated the effect of the magnetic field of the *JOIDES Resolution* on magnetometer readings made 300 m astern, finding an effect as high as 100 nT. However, up to 40 nT of this may be due to real magnetic variation according to the International Geomagnetic Reference Field (IGRF), leaving an effect of 60–100 nT. The greater 500 m tow length used in this survey further reduces the ship's magnetic effect by approximately two-thirds, for a final effect of 20–30 nT. The magnetic effect of the *JOIDES Resolution* is thus negligible compared to the typical observed anomalies of 250–500 nT, and no correction for the ship's magnetic field has been made. However, the position information logged with the magnetometer data has been corrected for the cable length.

Magnetic data were recorded at 3 s intervals, and these total intensity measurements were then reduced to magnetic anomalies using the 10th version of the IGRF (MacMillan and Maus, 2005) and filtered using the same fourth-derivative filtering technique used for the bathymetric data (as discussed above). However, for the magnetics data, only a single filtering pass was used, rejecting data points with a fourth derivative value of >50 nT/(sampling distance)^4. The data were then projected onto the same best-fitting great circle used for bathymetry.

Results

During Expedition 330, underway geophysical data were collected for 4691 km, divided into seven legs numbered sequentially as Transits L1T to L7T. The path of each transit is shown in Figures **F1** and **F2,** and the location and length of each transit are summarized in Table **T1.**

Transit L1T extends over 1500 km from Auckland to Site U1372 on Canopus Guyot and traverses the New Zealand continental shelf, the twin volcanic arcs associated with the Kermadec Trench, the trench itself, and finally the approach up the southwestern flank of Canopus Guyot (Fig. **F3**). The continental shelf has a slope of <0.2° and reaches a depth of 1000 m only after >300 km of transit. Relief over the two volcanic arcs is high, with a background depth of ~3000 meters below sea level (mbsl) marked by multiple small peaks and valleys in addition to the two main peaks at 1300 and 600 mbsl. The magnetic anomaly in this region is characterized by multiple peaks and troughs with wavelengths of ~50–100 km and amplitudes of 250–500 nT. Over the western arc, volcanic highs appear to correlate with magnetic highs, but this correlation becomes less distinct toward the east. The bathymetry on the portion of the overriding plate closest to the trench is comparatively flat and deep (typically 3000–4000 mbsl), sloping gently away from the eastern volcanic arc before taking on a distinctly convex shape as it approaches the trench. Here the magnetic anomalies are equally subdued (<150 nT), except for one pronounced high of 250 nT at 1225 km, apparently correlated with a small seamount. This subdued magnetic signature continues across the trench to the end of the profile. Depths over the trench are not well constrained but appear to be >8000 mbsl. The profile then rises sharply up the flanks of Canopus Guyot to 1950 mbsl.

Transit L2T extends southeast along the Louisville Seamount Trail from Site U1372 to Site U1373 on Rigil Guyot. It begins on the flat top of Canopus Guyot, which shallows slightly to 1400–1500 mbsl before deepening rapidly to a section of abyssal plain at 5100 mbsl (Fig. **F4**). The edge of Canopus Guyot is marked by a prominent positive magnetic anomaly of >600 nT. Transit L2T then crosses the flank of another Louisville seamount at 125–150 km, shallowing to 3450 mbsl, although depths are not well constrained, and then passes directly over another seamount at 195–235 km. This second seamount has the distinctive flat top of a guyot and rises to 1560 mbsl. Both of these seamounts are associated with strong negative magnetic anomalies of 1070 and 650 nT, respectively. Finally, the profile rises up the flanks of Rigil Guyot, shoaling at 1440 mbsl. Although the magnetic profile does not extend all the way up the guyot's flanks, Rigil Guyot appears to be marked by a substantial positive anomaly of >500 nT.

Transit L3T is a very short leg of just over 10 km between Sites U1373 and U1374 over the summit plain of Rigil Guyot and was too short for any magnetic data to be collected. The bathymetric data are quite noisy but show an essentially flat topographic profile at a depth of ~1500 mbsl (Fig. **F5**). The last kilometer of the transit is marked by a small dome-shaped feature with ~150 m of relief.

The next transit, Transit L4T, covers 580 km from Site U1374 on Rigil Guyot to Site U1375 on Achernar

Guyot. Bathymetric data are not available for the first 150 km of the transit; however, bathymetric data extracted from Smith and Sandwell (1994; v12.1) using the positioning information associated with the magnetics data show two small seamounts shoaling ~3000 mbsl, each associated with a strong positive magnetic anomaly of 500 and 800 nT, respectively (Fig. F6). From 100 to 550 km, the profile crosses abyssal plain with an average depth of 5600–6000 mbsl and magnetic anomalies of typically <100 nT. The satellite-derived bathymetry shows a single double-peaked seamount at 250 km, which aligns with a strong positive magnetic peak of >1000 nT. A negative magnetic anomaly of >500 nT occurs immediately to the north of the positive anomaly and appears to correlate with the northernmost summit of the double-peaked seamount. At the southern end of the profile are the flanks of Achernar Guyot, which shoals at 1265 mbsl.

No bathymetric data are available for Transit L5T, which extends north from Site U1375 on Achernar Guyot over several closely spaced seamounts in the Louisville Seamount Trail to Site U1376 on Burton Guyot. Bathymetric data from Smith and Sandwell (1994; v12.1) show the north flank of Achernar Guyot, deepening from 2000 to 4000 mbsl, followed by three small seamounts, all of which show some signs of the distinctive flat top of guyots (Fig. F7). The flanks of Burton Guyot at the northern end of the transect are not shown because the process of retrieving the magnetometer had begun by that point in the transit. Achernar Guyot is associated with a strong negative magnetic anomaly of nearly 1000 nT. Moving north along the transect, the second seamount is associated with a double-peaked negative magnetic anomaly as high as 720 nT, whereas the third has a strong positive anomaly of 880 nT. The northernmost seamount, however, has a magnetic anomaly that consistently decreases from ~200 nT on the southern side to about –750 nT on the northern side.

From Site U1376, the *JOIDES Resolution* transited more than 700 km to the south-southeast to Site U1377 on Hadar Guyot. Transit L6T thus crosses numerous small seamounts 1000–2000 m high, none of which show the flat tops characteristic of seamounts that were once subaerial (Fig. F8). The magnetic signature of these smaller seamounts is also more varied, with several, including those at 300, 450, and 500 km, showing a distinct positive or negative magnetic anomaly of >500 nT. However, the largest seamount in the profile, located at 625–675 km, has a much smaller (<250 nT) negative magnetic anomaly characterized by multiple peaks. The first 100 km of the profile also includes a pronounced magnetic low and highs of ~750 nT that are not associated with substantial volcanic features. The largest seamount in this interval, located at 60 km, is associated with a pair of very narrow anomalies: a positive anomaly of ~400 nT to the northwest and a negative anomaly of ~600 nT to the southeast; even larger anomalies are observed over the more subdued topography to either side of this seamount.

Transit L7T then covers 1450 km almost due west from Site U1377 on Hadar Guyot back to Auckland. For the first 700 km this profile traverses primarily abyssal plain with a depth of ~5000 mbsl, interrupted at ~450 km by a single double-peaked seamount with just over 1000 m of relief (Fig. F9). The magnetic anomalies along this profile are generally subdued, <250 nT in amplitude, but this seamount is associated with a positive anomaly of ~1200 nT. The profile then crosses a region of gradually shallowing and rougher topography, including two small seamounts and the southernmost tip of the Kermadec Trench, here a substantial smaller feature ~2000 m in amplitude. The profile then shallows to <200 mbsl for the last 100 km over the continental shelf.

References

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Figure F1. Location map showing geophysical track data collected during Expedition 330 to the Louisville Seamount Trail, together with the regional tectonic setting. Expedition 330 drill sites, together with the starting and ending port of Auckland, New Zealand, are marked with red dots. Heavy white lines show transit routes. Transit L3T between Sites U1373 and U1374 is too short to be visible on the map and thus is not labeled. Bathymetry is from Smith and Sandwell (1994; v12.1).

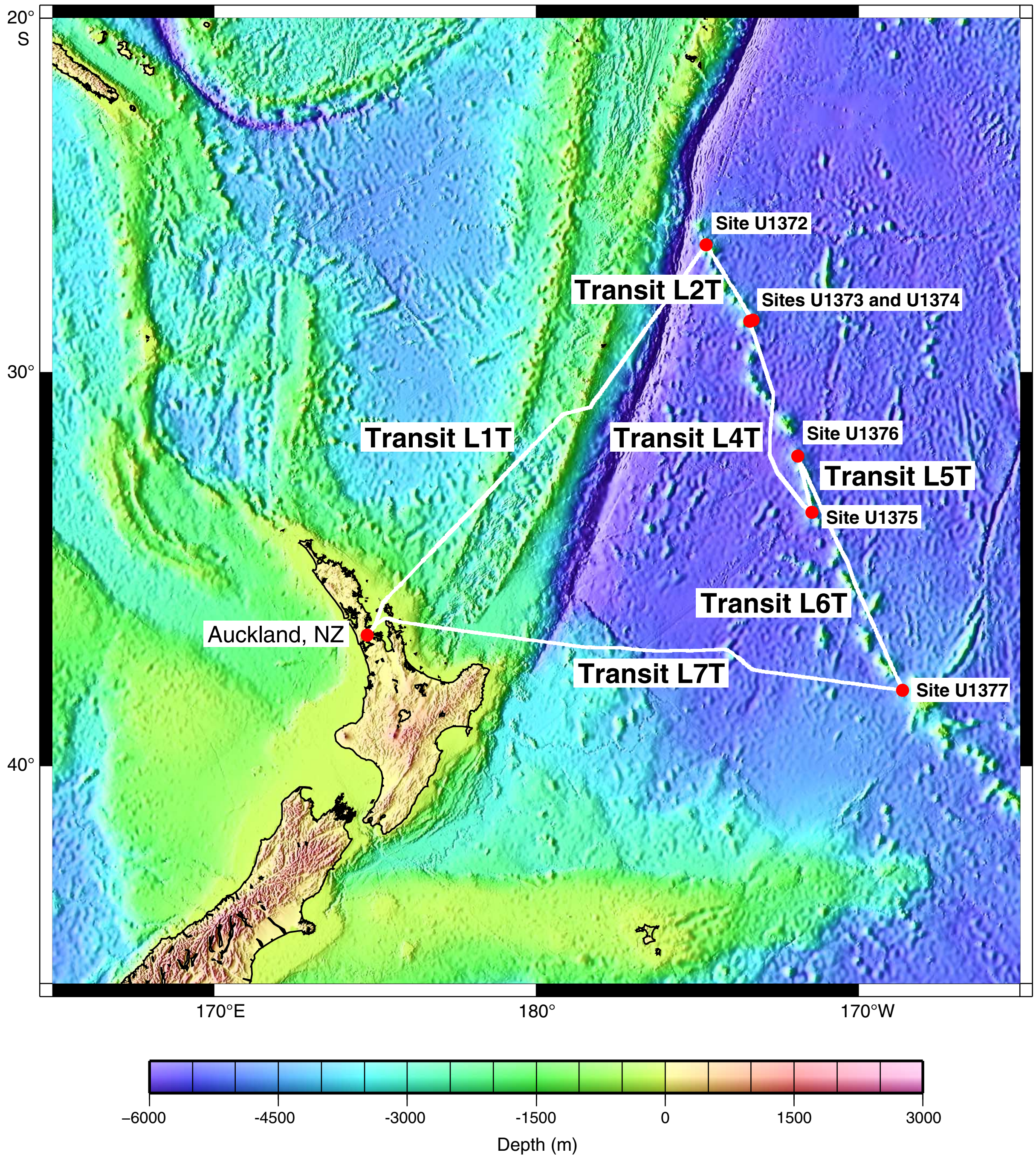

Figure F2. Location map showing transit routes over the Louisville Seamount Trail. Labeling is as in Figure F1. Note that Transit L3T was too short to be labeled.

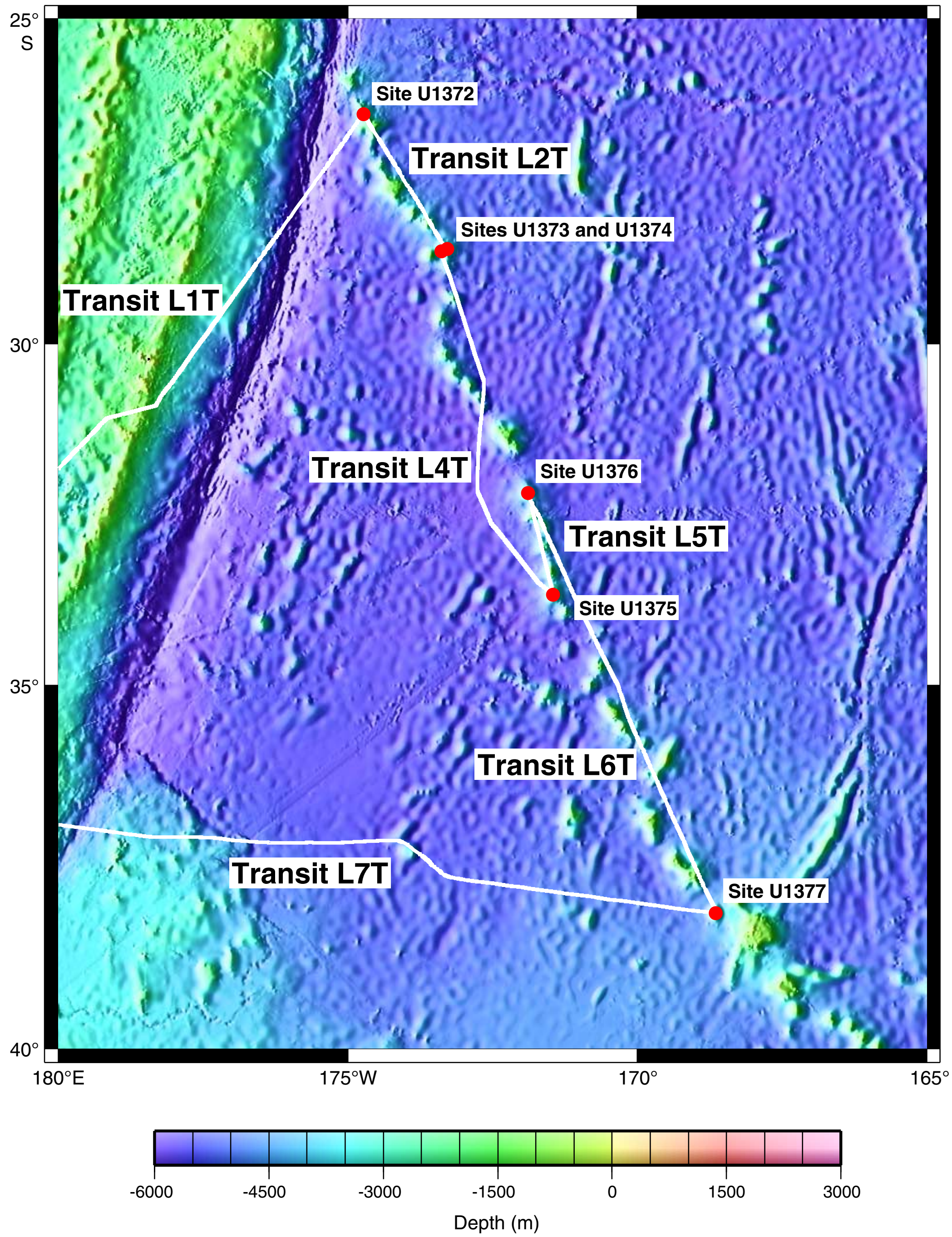

Figure F3. Magnetic anomaly, bathymetry, and echo sounder profiles of Transit L1T from Auckland, New Zealand, to Site U1372. Gaps of >5 km in the bathymetry data are marked with pale gray shading. See Figure F1 for location.

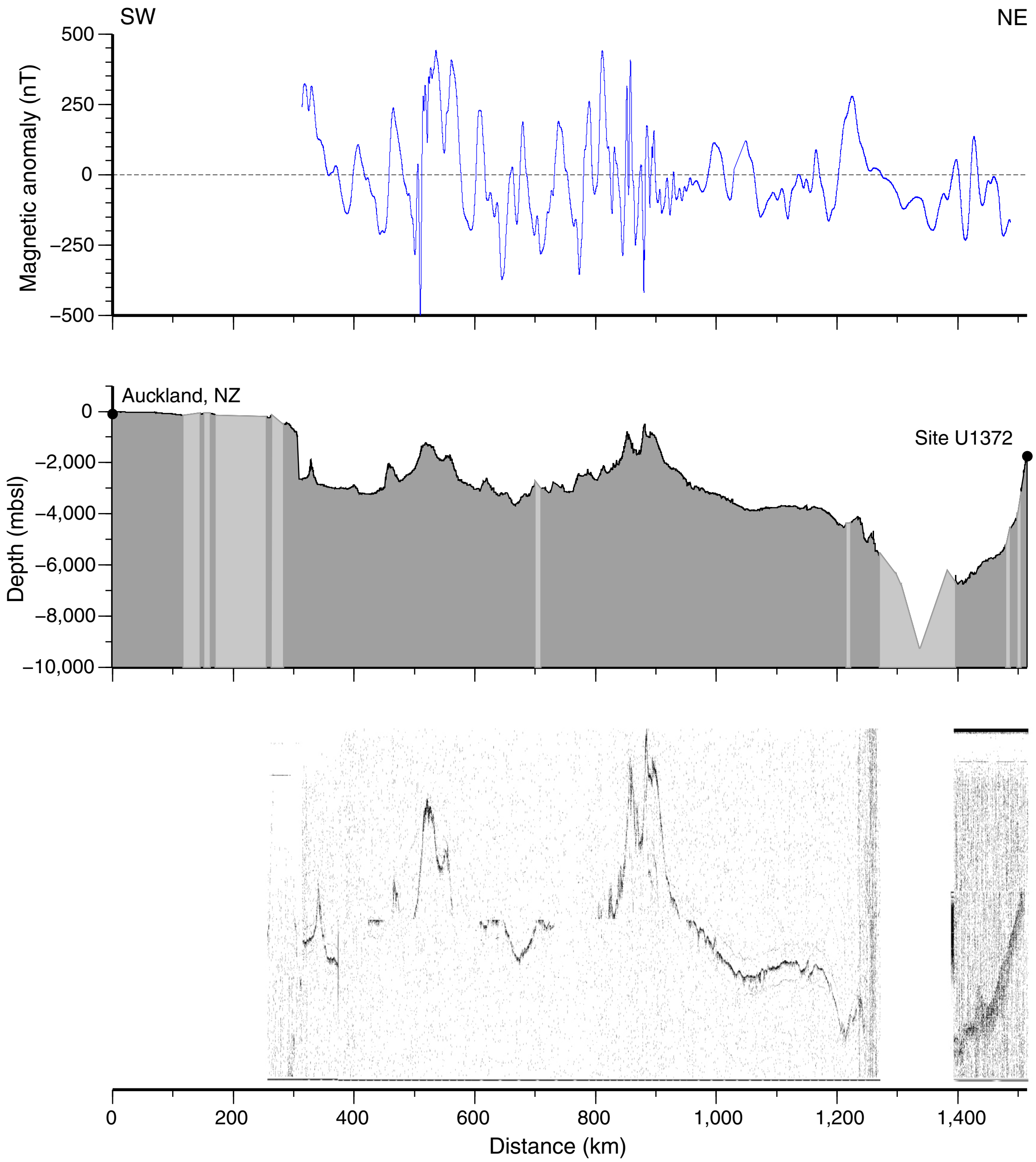

Figure F4. Magnetic anomaly, bathymetry, and echo sounder profiles of Transit L2T from Site U1372 to Site U1373. Gaps of >5 km in the bathymetry data are marked with pale gray shading. See Figure F2 for location.

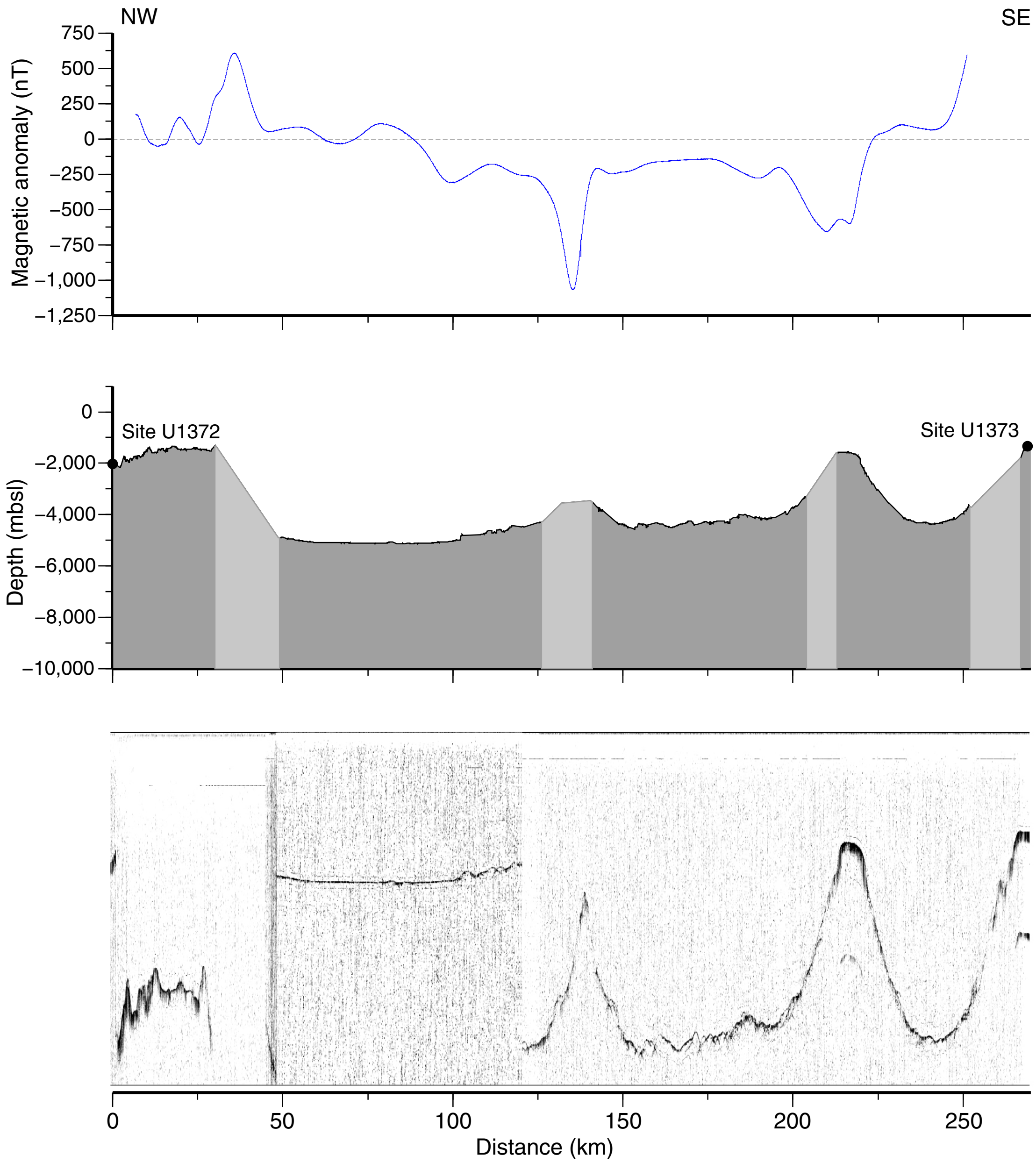

Figure F5. Bathymetry and echo sounder profiles of Transit L3T from Site U1373 to Site U1374. A bathymetric profile extracted from Smith and Sandwell (1994; v12.1) is also shown in green for reference. No magnetic data were collected because of the short length of the transit. See Figure F2 for location.

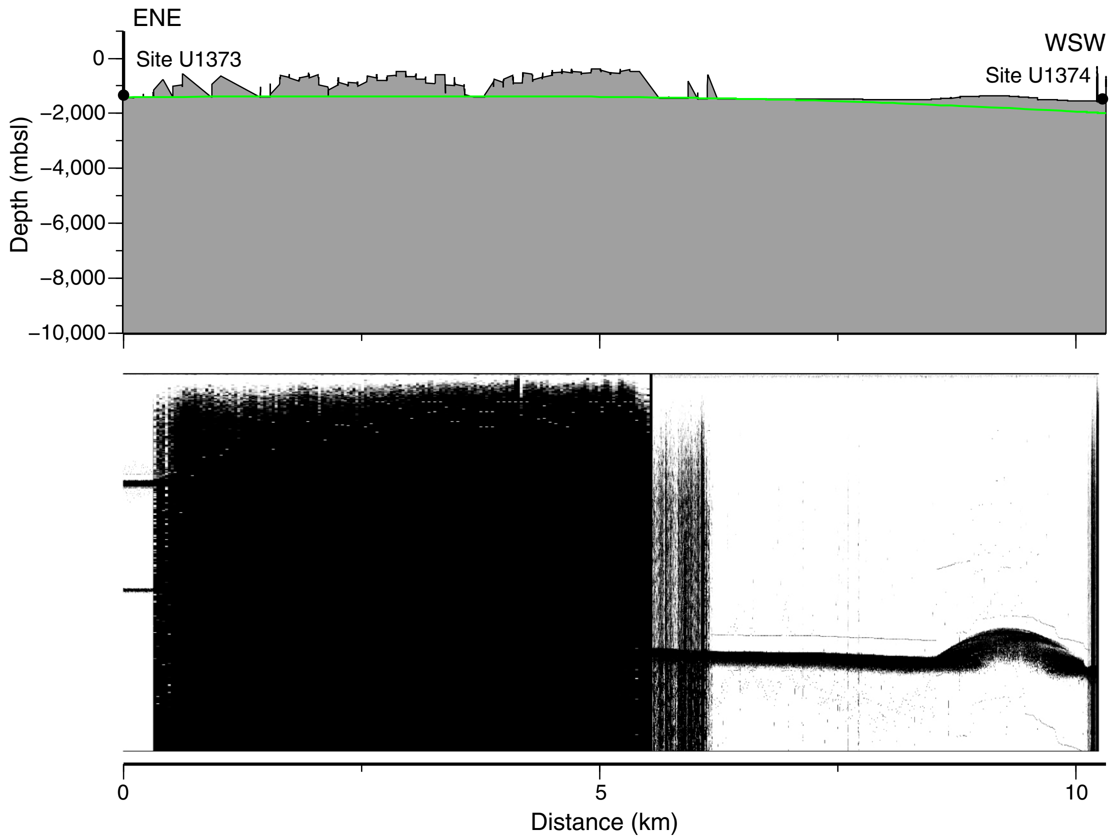

Figure F6. Magnetic anomaly, bathymetry, and echo sounder profiles of Transit L4T from Site U1374 to Site U1375. Gaps of >5 km in the bathymetry data are marked with pale gray shading. A bathymetric profile extracted from Smith and Sandwell (1994; v12.1) is also shown in green for reference. See Figure F2 for location.

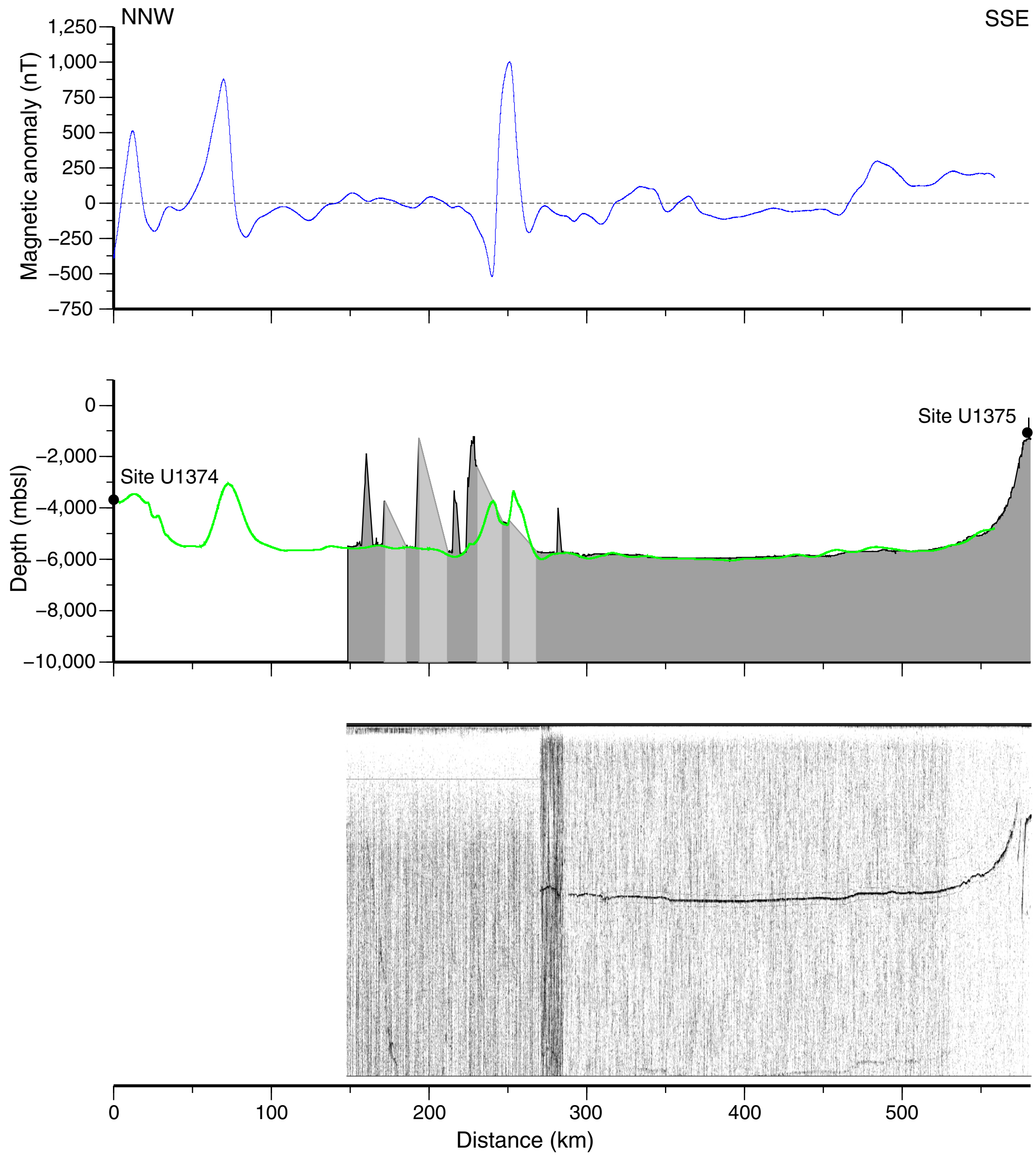

Figure F7. Magnetic anomaly profile of Transit L5T from Site U1375 to Site U1376, together with a bathymetric profile extracted from Smith and Sandwell (1994; v12.1), shown in green. No bathymetric or echo sounder data are available for this transit. See Figure **F2** for location.

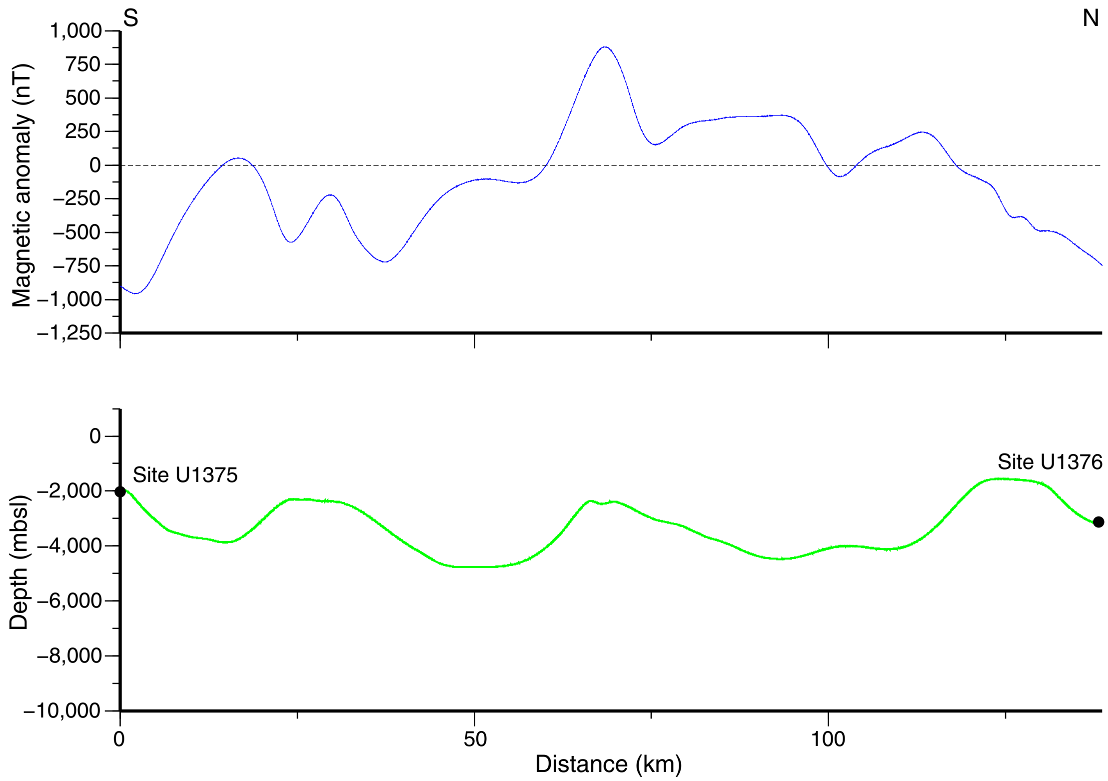

Figure F8. Magnetic anomaly, bathymetry, and echo sounder profiles of Transit L6T from Site U1376 to Site U1377. Gaps of >5 km in the bathymetry data are marked with pale gray shading. See Figure F2 for location.

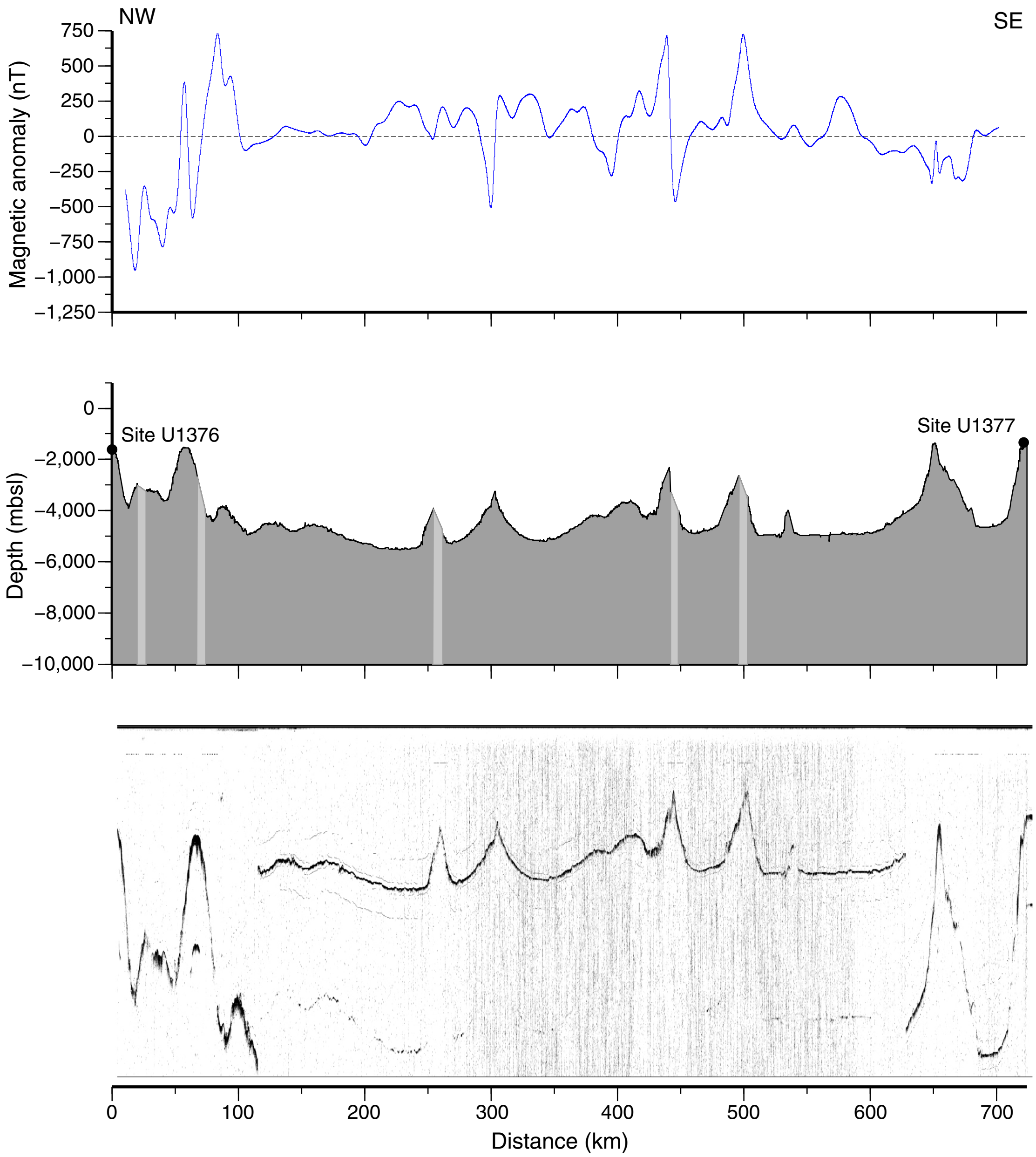

Figure F9. Magnetic anomaly, bathymetry, and echo sounder profiles of Transit L7T from Site U1377 to Auckland, New Zealand. The largest gap in the magnetic data, from 121 to 218 km, is due to a loss of GPS positioning data; the two smaller gaps are due to a loss of magnetic data. Gaps of >5 km in the bathymetry data are marked with pale gray shading. Note that echo sounder profiles on the continental shelf have increased vertical exaggeration. See Figure F1 for location.

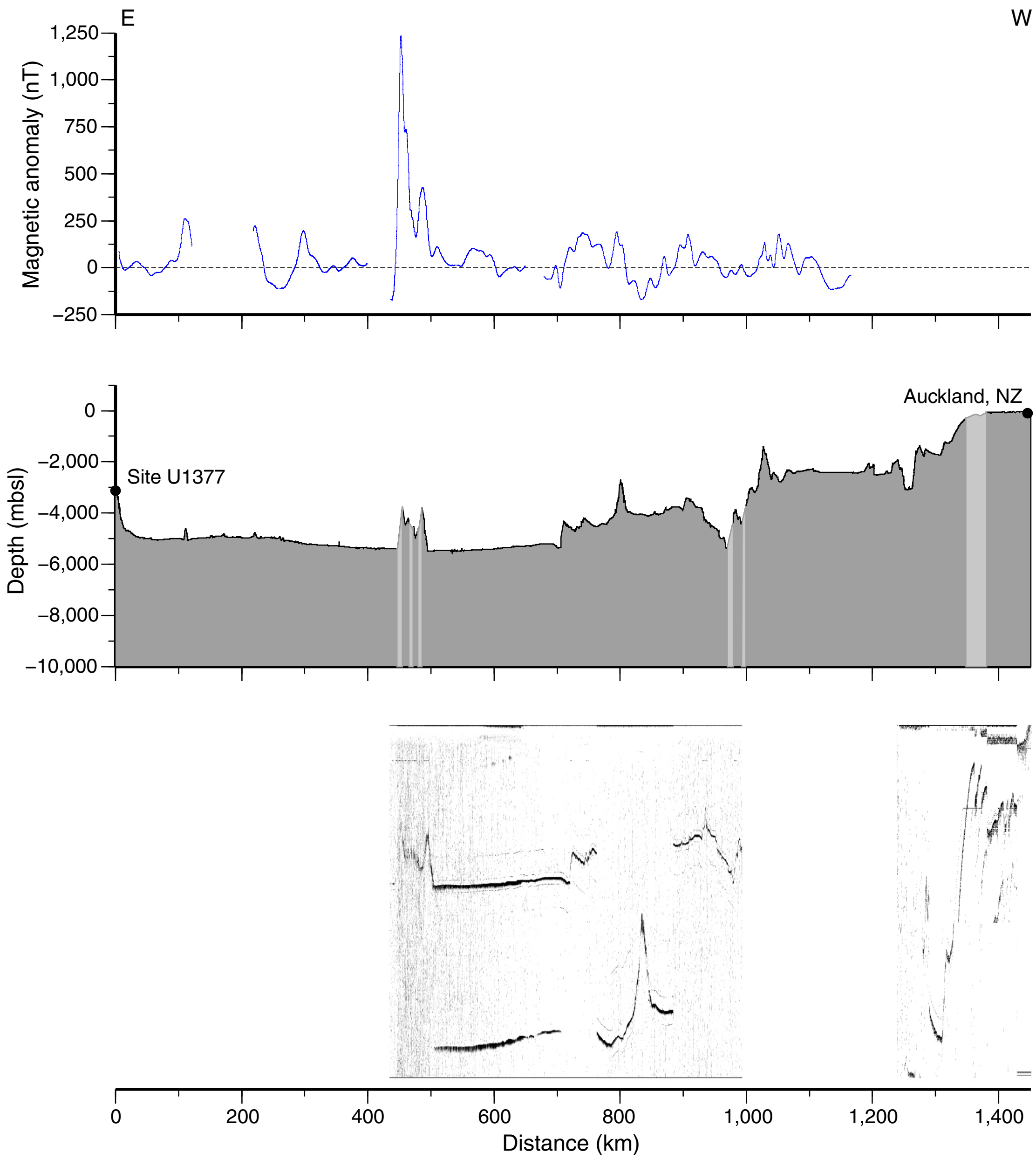

Table T1. Transit information for Expedition 330, including starting and ending location and length of each transit. Given lengths are based on projections onto a best-fitting great circle and thus underestimate the true distance when transit routes are irregular.

Transit	Start	End	Length (km)	Comments
L1T	Auckland, New Zealand (36.82°S, 174.75°W)	Site U1372 (26.49°S, 185.27°W)	1515	
L2T	Site U1372, Canopus Guyot (26.49°S, 185.27°W)	Site U1373 (28.57°S, 186.72°W)	270	
L3T	Site U1373, Rigil Guyot (28.57°S, 186.72°W)	Site U1374 (28.60°S, 186.62°W)	10.3	No magnetic data available
L4T	Site U1374, Rigil Guyot (28.60°S, 186.62°W)	Site U1375 (33.70°S, 188.55°W)	582	
L5T	Site U1375, Achernar Guyot (33.70°S, 188.55°W)	Site U1376 (32.22°S, 188.12°W)	139	No bathymetric or echo sounder data available
L6T	Site U1376, Burton Guyot (32.22°S, 188.12°W)	Site U1377 (38.18°S, 191.36°W)	724	
L7T	Site U1377, Hadar Guyot (38.18°S, 191.36°W)	Auckland, New Zealand (36.82°S, 174.75°W)	1451	Loss of position data for ~100 km of magnetic data