IODP Expedition 317: Canterbury Basin Sea Level

Site U1354 Site Summary

3 January 2010

Hole U1354A
Position: 44° 50.8281' S Latitude, 171° 47.2096' E Longitude
Water Depth: 109.8 m (based on mudline recovered with APC)
Penetration Depth: 85.4 m DSF
Recovered Core: 84.43 m (101%)
Time on Hole: 28 December, 2345 h through 29 December, 2300 h

Hole U1354B
Position: 44° 50.8367' S Lat, 171° 47.2069' E Long (20m south from Hole U1354A
Water Depth: 113.4 m (based on mudline recovered with APC)
Penetration Depth: 77.2 mbsf
Recovered Core: 77.52 m (10%)
Time on Hole: 29 December, 2300 h through 30 December, 1245 h

Hole U1354C
Position: 44° 50.8487' S Lat, 171° 47.2080' E Long (20m south from Hole U1354B)
Water Depth: 113.4 m (adopted from Hole U1354B)
Penetration Depth: 384.2 m DSF
Advanced without Coring: 65.0 m
Cored Interval: 319.2
Recovered Core: 133.37 m (42%)
Time on Hole: 31 December, 0700 h through 30 December, 1245 h

Background

Site U1354 (proposed Site CB-02A; 110 m water depth) is located on the mid-outer shelf within the Canterbury Bight between landward shelf Site U1353 (proposed Site CB-01A) and outer shelf Site U1351 (proposed Site CB-03B) within the Canterbury Basin drilling transect. Site U1354 occupies an intermediate position in the shelf portion of the Expedition 317 transect. Lithologies and paleoenvironments should therefore be intermediate between those found at Sites U1351 and U1353.

Site U1354 penetrates a middle Miocene to Pleistocene section containing seismic sequence boundaries U8 to U19. All sequence boundaries are penetrated landward of their rollovers, or paleo-shelf edges with the goal of recovering proximal facies, yielding evidence of shallow-water deposition, and providing optimal paleo-water depths from benthic foraminiferal biofacies.

The principal objectives at Site U1354 were:

1. Sample facies landward of rollovers of progradational sequence boundaries U8-U19. A particular goal is to use benthic foraminiferal biofacies to estimate paleo-water depths both above and below sequence boundaries. This information will be used to calculate eustatic amplitudes using two-dimensional backstripping.

2. Investigate the facies, paleoenvironments and depositional processes associated with the sequence stratigraphic model in a proximal setting on a prograding continental margin where sequence architecture is well constrained by seismic imaging.

Operations

After a 7 nm transit from Site U1353, the vessel was positioned over Site U1354 (proposed site CB-02A) at 2320 h (UTC+13h) on 28 December 28. Three holes were cored with the APC/XCB coring system at Site U1354. The third hole was drilled with a center bit installed to 65 m DSF to advance the hole after severe weather ended Hole U1354B. Logging of Hole U1354C was successfully completed with a special tool configuration that minimized risk and maximized logging data return. The SET temperature tool was deployed twice without success. The type of formation encountered proved too difficult for our temperature measurement tools. Overall recovery for Site

U1354 was 100% with the APC coring system and 39% with the XCB system. The total cored interval for Site U1354 was 479.8 m with 294.50 m (61%) of recovery.

Coring in Hole U1354A began at 0415 h on 29 December and APC coring continued through Core U1354A-19H to a depth of 85.4 m DSF using non-magnetic coring assemblies. A 2-m section (64.9 - 66.9 m DSF) had to be drilled to advance through a section of shells and shell fragments. Core orientation was measured on the first three cores, but hard formation and incomplete piston strokes prompted a decision to remove the tool. Temperature measurements were not attempted on this hole because of poor hole conditions. Waiting for 10 minutes without circulation in shallow water was deemed too risky. Overall recovery for Hole U1354A using the APC coring system was 100%.

The vessel was offset 20 m south of Hole U1354A and Hole U1354B was piston cored to a depth of 77.2 m DSF with a total recovery of 77.52 m (100%). Because of the rough piston coring conditions noted in Hole U1354A, the core orientation and downhole temperature tools were not deployed. Coring was terminated at 77.2 m DSF because highly variable winds from the south caused positioning problems. Unable to keep the vessel within the required watch circle, the decision was made to wait on the weather to improve. The drill string was tripped back to just above the sea floor and the bit cleared the sea floor at 1245 h on 30 December, ending Hole U1353B.

Operations in Hole U1354C began at 0700 h on 31 December when the vessel was again able to maintain its watch circle over the new location. The ship was offset 20 m south from Hole U1354B. The hole was drilled to 65 m DSF with the center bit installed before two APC cores were taken. The core liner shattered on the second

attempt and the APC system was replaced with the XCB system to core through a particularly dense layer of shells. Core recovery with the XCB was initially very good but deteriorated downhole. Coring with the XCB continued to 384.2 m DSF (Core U1354C-36X). The total penetration for Hole U1354C was 384.2 m. The total cored interval for Hole U1354C was 319.2 m, with 133.37 m of core recovered (42%).

The hole was swept clean with a 50-barrel high viscosity mud sweep and displaced with 320 barrels of high viscosity 10.5 ppg logging mud. A special logging string was made up in order to get all basic sensors without nuclear sources into a single run. The string provided resistivity (DIT), sonic compressional and shear (DSI), and natural gamma ray spectroscopy (HNGS) tools. The tool string tagged the bottom of the hole at ~505 m WRF. After a short "repeat section" was recorded from TD up to ~440 m WRF, the tool string was returned to TD and then recorded a main pass up to the seabed. The drill string was tripped back to 275 m DRF and a 12-barrel, 14-ppg cement plug was pumped. The logging tools were rigged down, the drill string was tripped to surface and the bottom hole assembly was broken down and secured for transit. After the beacons were recovered and the rig was secured for transit, operations at Hole U1354C, at Site U1354, and on Expedition 317 ended at 1200 h on 2 January and the vessel departed for the 24-h transit to Wellington.

Lithostratigraphy

Site U1354 drilled Quaternary to Early Pliocene sediments located in water depths and position between Site U1351 on the outer shelf, and Site U1353 on the mid-shelf. It provides an excellent sedimentary record of deposition through the Holocene-Quaternary period of eustatic sea-level fluctuation. Hole U1354C penetrated some of the

older Early Pleistocene-Pliocene seismic reflectors in the offshore Canterbury Basin, which at this site, are at relatively shallow sub-bottom depths. Core recovery was reduced below 175 m CSF, which hindered lithostratigraphic interpretation of the deeper parts of the section.

Lithologic changes suggest a progressive and gradual change in sedimentary style as the margin evolved and are consistent with similar observations made at the other shelf sites. Cores recovered from Holes U1354A, U1354B, and U1354C show a downhole transition from a heterolithic upper section between 0 – 250.81 m CSF with abrupt contacts (Unit I), to a more featureless mud-dominated succession below 250.81 m CSF (Unit II). Unit I is further subdivided into an upper Subunit IA (0 – 145.8 m CSF), and a lower Subunit IB (145.8 – 250.81 m CSF).

Subunit IA is more heterolithic, containing dark greenish gray to olive gray calcareous muddy sand, sandy marl, and homogeneous marl and very dark gray massive quartz-rich very well-sorted very fine – fine sand. It also contains examples of sharp, bioturbated contacts between very fine muddy sand, sometimes calcareous, above and silty mud below. In contrast, Subunit IB lacks the aforementioned olive gray marls and massive sands, and is characterized by more repetitive assemblages of facies that consist of homogeneous greenish gray mud, which appears to be more clay-rich than Subunit IA and also contain a minor calcareous component, and greenish gray to gray calcareous sandy mud to sandy marl that often contains calcareous concretions.

The dominant lithology of Unit II consists of very dark and dark greenish gray to gray, micaceous, very fine sandy mud and mud, typically with shells. Both types of sediment have variable degrees of bioturbation ranging from absent to moderate

(bioturbation indices of 1 to 3). Muddy very fine sand with shells occurs as a minor lithology.

Site U1354 is interpreted to represent a slightly more shoreline proximal equivalent of Site U1351, but for Unit I, appears to represent a shallower-water, inner shelf setting both in relation to Sites U1351 and U1353. This is surprising in respect to Site U1354, which is today in shallower water. Evidence for shore face and sub-tidal deposition, including potential paleosols, suggest that Unit IA at Site U1354 might represent a shoaled region of deposition. Several sharp and also subtle contacts, along with biostratigraphic evidence for hiatuses, are evidence that sea-level variations controlled depositional facies of Unit I. Unit II represents inner- to mid-shelf depositional settings during the Pliocene at the site. Potential lithologic expression of seismic sequence boundaries can be matched between all three shelf sites.

Biostratigraphy

The Holocene to late early Pliocene biostratigraphy of Site U1354 was based on the shipboard study of calcareous nannofossils, diatoms, and planktic and benthic foraminifers in core-catcher samples from Holes U1354A, U1354B and U1354C. Additional intra-core samples were taken from selected cores to address specific age and paleoenvironmental questions using calcareous nannofossils. All microfossils groups were represented throughout the cored section, except for diatoms, which were only found in a few Pleistocene samples.

The Holocene to Pleistocene section in Hole U1354A (3.78-85.4 m), Hole U1354B (4.1-77.3 m), and Hole U1354C (0-127.8 m) was primarily dated and subdivided with calcareous nannofossils into zones NN21-NN19. Two hiatuses were identified from

nannofossil dating: an intra-Pleistocene hiatus at 57.7-62.4 m in Hole U1354A and at 73.7-73.9 m in Hole U1354B, where ~0.3 m.y. was missing; and at the base of the Pleistocene, at 122.2-133.4 m in Hole U1354C, where ~1 m.y. was missing. Another potential hiatus was identified on the basis of calcareous nannofossil dating and magnetostratigraphic data at Holes U1354A and U1354B, at 69.9 m and 64.8 m, respectively. Benthic foraminifers were generally indicative of subtidal to middle shelf depths through the Pleistocene, and planktic foraminifers suggested deposition was generally under sheltered inner neritic conditions, except for short-lived excursions to outer neritic and extra-neritic conditions.

The Pliocene section between 133 and 375 m was poorly dated, although calcareous nannofossil and planktic foraminifers dating suggest the age of the section is middle Pliocene (>2.78 Ma, calcareous nannofossils) to late early Pliocene (>4.3 Ma, planktic foraminifers). There was no biostratigraphic evidence for the late Pliocene and it is probably missing at the level of the basal Pleistocene hiatus. Pliocene deposition was generally in inner shelf water depths, ranging possibly to middle shelf depths at times, under sheltered inner neritic conditions. The age at the bottom of Hole U1354C (357.3 m), as constrained by calcareous nannofossils and planktic foraminifers, was late early Pliocene–Miocene (3.7-4.3 Ma).

Paleomagnetism

Natural remanent magnetization was measured before and after demagnetization at 20 mT peak fields, where possible at this site. Persistent flux jumps in the SRM rendered measurement difficult, and in some cases impossible in the time available. In spite of this, a good unambiguous record was recovered. The use of non-magnetic core

barrels throughout the overlapping Holes U1354A and U1354B allowed the identification of sediments holding reverse polarity from about 69.9 m and 65 m CSF downhole, respectively. The B/M boundary lies within an unconformity marked by a sharp lithological boundary in both holes. Hole U1354C began coring just beneath this boundary, and revealed sediments with reverse polarity of Matuyama age at its top. Biostratigraphic constraints indicate that the Jaramillo normal Chron (C1r.1n, 0.998-1.072 Ma) has not been recorded in sediments from Site U1354. Below 78.1 m CSF coring in Hole U1354C used the XCB system, which imparted a pervasive drilling overprint not fully removed during shipboard analyses.

Physical Properties

Magnetic susceptibility, natural gamma radiation and color records show pronounced variations in the upper ~170 m in all three holes, and these variations are similar to the patterns observed at previous Expedition 317 sites. Changes in magnetic susceptibility, natural gamma radiation and color can be linked to change in lithology. Color changes in particular highlight the utility of this parameter for distinguishing between low gamma ray and magnetic susceptibility sands and marls. Abrupt changes in these records at 34 and 54 m also coincide with two observed also with two observed sulfate–methane transitions in Hole U1354A.

P-wave measurements yielded good results over the upper 217 m. Good results were also gained from measurements made at Site U1353. At both sites the long record of good P-wave data can be ascribed to the absence of sediment fracturing caused by high gas content. A change between ~68 and 70 in Hole U1354A and between 64 and 65 m in Hole U1354B marks both a hiatus and the position of the Brunhes/Matuyama boundary.

This boundary can also be recognized in the natural gamma radiation, magnetic susceptibility, and color data.

Porosity and void ratio decrease and bulk density show changes compatible with the porosity trends seen at the other three Expedition 317 sites. The grain density shows some scatter, reflecting the variable lithology. Sediment strength measurements show a similar pattern to that observed at all Expedition 317 sites.

Geochemistry

Gaseous hydrocarbon monitoring at Site U1354 showed two peaks in methane content, one at 33-75 m, where HS methane increased to a peak of 23 ppmv at 46 m, and below about 200 m where HS methane increased above 20,000 ppmv. Where sulfate is zero, methane starts to build up, then decreases to near background concentrations at 60 m, the depth where sulfate reappears in the cores. Sulfate is also fully depleted below 200 m. The upper methane zone corresponds to a zone of rapid sedimentation, above which sulfate was depleted fast by both organic matter oxidation (one-third) and anaerobic methane oxidation (two-thirds). In the 60-178 m depth interval the stochiometry suggest that sulfate reduction was driven almost exclusively by anaerobic methane oxidation, and apparently the sediments in this depth interval were deposited at a rate slow enough to permit continuous replenishment of dissolved sulfate by diffusion from overlying seawater.

One notable aspect of the shallow pore water chemistry profiles at U1354 is the lack of a low-salinity zone, which was seen at the more on-shore site U1353 at about 50 m. This helps clarify the origin of this low-salinity zone. As the water depth at Site U1354 is only slightly deeper than at Site U1353, there is no reason to believe that these

sites have had a significantly different exposure during lowstands caused by glaciation. Therefore, the presence of this less-saline lens at Site U1353 is most likely explained by modern intrusion of meteoric water from land, rather than by the historic remains of freshwater emplaced when the shelf was emergent.

Other changes in pore water chemistry at Site U1354 are probably related to carbonate diagenesis and possible contributions from deeper basinal brines. The main decreases in dissolved calcium and magnesium occur within the depth intervals characterized by sulfate reduction, methanogenesis, and anaerobic methane oxidation. These processes are commonly associated with precipitation of authigenic carbonates with distinct carbon isotopic compositions. The increase in sodium and chloride from 0 to 60 m, possibly related to an influx of saline fluid, may also account for some of the other changes seen in Site U1354, such as the increases in barium, lithium and boron with depth.

Only eighteen sediment samples were analyzed for carbonate content and by the elemental analyzer due to time constraints at the end of the expedition. Calcium carbonate contents range from 1.3 to 52 wt% in the sediments analyzed down to burial depths of 81 m. Organic carbon ranges from 0.02 to 1.1 wt%, with the highest value at a depth of 50 m. The ratio of total organic carbon to total nitrogen generally decreases with depth, with the exception of some of the high carbonate samples in the 73-76 m depth interval.

Heat Flow

Two temperature measurements were made using the SET with Core U1354C-14X and -16X, but results were poor due to the harsh coring conditions. Accordingly, it

was impossible to determine the geothermal gradient and heat flow at U1354. Thermal conductivity ranged from 1.183-1.873 W/m·K showing constant profile with depth. Overall thermal conductivity correlated negatively with porosity and positively with bulk density. However, the highest values above 1.700 W/m·K came from very fine-fine sand layers in Holes U1354A and U1354B that were not associated with low porosity and high bulk density, probably because the sand layers consist mainly of high thermal conductive material such as quartz.

Downhole Logging

Downhole logging of Hole U1354C took place on January 2, 2010. Based on the potential for unstable hole conditions, our previous experience logging shelf sites, and time constraints at the end of the expedition, it was decided that a single logging run without radioactive sources was the most reasonable approach for the last site. A modified "Sonic Combo" toolstring was deployed, measuring natural gamma ray, sonic velocities, and electrical resistivity from seafloor to a total depth of 383 m WSF (wireline depth below seafloor).

Two units were identified in the logs. Logging Unit 1 (110-285 m WSF) is characterized by an increasing trend in gamma ray from the top of the unit to ~185 m WSF, followed by a generally decreasing trend to the base of the unit, punctuated by abrupt high-amplitude lows in gamma ray and peaks in resistivity and velocity. This unit is identical to Logging Unit 1 at Site U1353 and the high-amplitude features at both sites correspond to coarser-grained intervals in cores. Preliminary synthetic seismograms show that the two most prominent of these sand-rich intervals coincide with seismic reflectors U10 and U11. Logging Unit 2 (285-384 m WSF) is characterized by slightly decreasing

trends in gamma ray and resistivity, with limited variability, and increasing velocity. Unit 2 at this site is similar to Logging Unit 2 at Site U1353, which is characterized by low core recovery associated with sandy sediments.