IODP Expedition 342: Paleogene Newfoundland Sediment Drifts
Site U1409 Summary

Background and Objectives

Site U1409 (proposed site SENR-22A; 41° 17.75'N, 49° 14.00'W) is a mid-depth site (~3500 m; ~3050 m paleodepth at 50 Ma, Tucholke and Vogt, 1979), in the upper mid-depth end of the Expedition 342 Paleogene Newfoundland Sediment Drifts depth transect. The site is positioned to capture a record of sedimentation around 1.5 km shallower than the largely sub-carbonate compensation depth record drilled at IODP Site U1403. Site U1409, therefore, is located well above the average late Paleogene carbonate compensation depth and should be sensitive to both increases and decreases in carbonate burial, whether these reflect variations in dissolution related to changes in the CCD, changes in carbonate production, or variations in background non-carbonate sedimentation. Site U1409 is a companion site to Site U1410 where we employ an offset drilling strategy to obtain APC/XCB records through a thicker section of the same sediment drift than would be possible by drilling a single site. Our objective at Site U1409, situated at the edge of the sediment drift, was to penetrate a more condensed Middle Eocene sequence than anticipated in the mid-section of the drift, making it possible penetrate Lower Eocene and Paleocene sediments at relatively shallow burial depth (<250 m).

Principal Results

The vessel arrived at Site U1409 (proposed site SENR-22A) at 1010 h (UTC-2.5h) on 16 July 2012, after a 26.3 nmi transit from Site U1408 that took 3.0 hours at 8.8 nmi/hr. The pipe trip to the seafloor was interrupted at 2863.3 m drilling depth below rig floor (DRF) for a test of the subsea camera system, which had been damaged at Site U1403, but strong ocean currents led to the early termination of the test. After completing the pipe trip, Cores U1409A-1H through 16H were recovered to 127.0 m drilling depth below seafloor (DSF) using non-magnetic core barrels and the FLEXIT core orientation tool. Core U1409A-15H experienced the first partial stroke and the APC system was advanced by recovery to Core U1409A-16H. The XCB system was deployed for Cores U1409A-17X through 26X to 200.1 m DSF. The seafloor was

cleared at 0550 h on 18 July, ending Hole U1409A. Overall core recovery for Hole U1409A was 183.33 m for the 200.1 m interval cored (92% recovery). The total time spent on Hole U1409A was 43.5 hours.

The vessel was offset 20 m to the east and Cores U1409B-1H through 14H were retrieved to 122.5 m DSF using non-magnetic core barrels and the FLEXIT core orientation tool. The XCB system was deployed for Cores U1409B-15X through 19X to 170.5 m DSF. The seafloor was cleared at 0340 h on 19 July, ending Hole U1409B. The recovery for Hole U1409B was 167.09 m over the 170.5 m cored (98% recovery). The total time spent on Hole U1409B was 22.0 hours. The vessel was offset 20 m to the south and Cores U1409C-1H through14H (124.2 m DSF) were retrieved using non-magnetic core barrels. Core orientation was not performed on Hole U1409C. XCB coring continued from Core U1409C-15X through 21X to the final depth of 160.8 m DSF. The recovery for Hole U1409C was 160.98 m over the 160.8 m cored (100% recovery).

The drill string was pulled to ~3200 m DRF and the rig prepared for a transit in dynamic positioning mode to Site U1410. Poor weather conditions and high surface currents foiled the recovery of the beacon, which was declared lost at 1515 h on 20 July, ending Hole U1409C. The total time spent on Hole U1409C was 35.5 hours. The overall percentage recovery for Site U1409 was 96%. The total time spent on Site U1409 was 101.0 hours or 4.2 days.

Four lithostratigraphic units were described in the ~200 m thick sedimentary succession of deep-sea pelagic sediments recovered at Site U1409. Unit I contains alternating brown to reddish brown Pleistocene silty clay and nannofossil ooze with varying abundances of foraminifers and diatoms and occasional layers of muddy sand with foraminifers. Both the Unit I/II and Unit II/III boundaries are erosive contacts. Unit II is a heavily bioturbated, light yellowish brown Oligocene silty clay to nannofossil clay, containing manganese nodules, patches of disseminated sulfides, and rare concentrations of faint red oxide horizons. Unit III contains alternating beds of light greenish grey nannofossil clay and white nannofossils ooze. Some intervals are associated with oxide horizons and dampened color contrast between adjacent beds. Unit IV contains lithologies ranging from pinkish white nannofossil ooze with

varying abundances of radiolarians and foraminifers to dark brown claystone, siliceous limestone, and chert. The Middle Eocene to Early Paleocene sediments of Unit IV are subdivided into three subunits. Subunits IVa–IVc contain i) pinkish white nannofossil oozes with radiolarians, ii) frequent cherts and highly varied lithologies including pink to dark brown or grey nannofossil ooze to chalk with interbedded chert, siliceous nannofossil limestone, and nannofossil claystone, and iii) pink to pale grey or pale brown nannofossil chalk.

Nannofossils, planktic foraminifers and benthic foraminifers are present through most of the Pleistocene to lower Paleocene succession although all microfossil groups are absent through a short interval between the Pleistocene and Oligocene. Radiolarians are only present in the uppermost Pleistocene and the lower middle Eocene through to the upper Paleocene. Thin Pleistocene and Oligocene sequences overlie a middle Eocene through lower Paleocene succession with significant hiatuses between the lower Pleistocene and upper Oligocene (22 my duration) and lower Oligocene and middle Eocene (8.3 my duration). A short hiatus or condensed interval is also identified at the Paleocene/Eocene boundary. The Oligocene is highly condensed and may contain significant hiatuses. Sedimentation rates are 0.68-1.31 cm/ky through the middle Eocene, 0.51-1.44 cm/ky through the lower Eocene, and ~0.47-1.80 cm/ky through the Paleocene.

Magnetochronology reveals a series of normal and reverse magnetozones between Cores U1409A-1H and 13H (~0-115 m core depth below seafloor [CSF-A]), between Cores U1409B-1H and 13H (~0-120 m CSF-A), and between Cores U1409C-1H and 13H (~0-115 m CSF-A). These magnetostratigraphies are straightforward to correlate among all three holes and primarily consist of two time intervals. The first is from lower Chron C6Cr (~23.9 Ma) through upper Chron C13r (~33.7 Ma); the second is from lower Chron C19r (~42.3 Ma) through upper Chron C22r (~49.4 Ma). Chrons C9n, C9r, and C10n.1n are not observed in any hole at Site U1409, indicating a hiatus at ~27.5 Ma. The C13n/C13r chron boundary (33.705 Ma) is tentatively identified in Section U1409A-5H-2, between Sections U1409B-4H-5 and 4H-6, and in Section U1409C-5H-2. The magnetochronology suggests that sedimentation rates were ~0.3 cm/ky through the Oligocene and varied between ~0.5 and ~1.3 cm/ky across the

Middle Eocene. Sedimentation rates were higher before the Middle Eocene Climatic Optimum (MECO, ~41.5 Ma) than post-MECO, similar to results from Site U1408.

Bulk density shows a general increase downhole from 1.40 to 1.95 g/cm^3 with a superimposed abrupt step decrease to ~1.5 g/cm^3 at the transition between lithostratigraphic Units I and II. Grain density averages 2.75 g/cm^3 in Hole U1409A. Overall in Hole U1409A, water content and porosity show a decreasing trend downhole (from 25% to 60% and from 45% and 80%, respectively). At ~15 m CSF-A, water content and porosity both show a decrease associated with the major hiatus between the Oligocene and Eocene. P-wave velocity increases progressively downhole from 1500 to 1800 m/s. Magnetic susceptibility decreases from ~120 to 30 IU at 18 m CSF-A and remains near-constant (~9 IU) to the bottom of the sediment column except for three notable peaks within lithostratigraphic Unit III at ~50, ~72, and ~90 m CSF-A corresponding to oxide-rich layers. Color reflectance parameters a* and b* show very distinct downhole variation throughout the sediment column. Natural gamma radiation (NGR) and L* show five major peaks at ~38, 47, 70, 100 and 155 m CSF-A, all of which correlate with the major variations in calcium carbonate content. Almost all physical properties show a shift or a peak at ~155 m CSF-A associated with the Paleocene Eocene Thermal Maximum (PETM) event.

The stratigraphic splice constructed for Site U1409 is stratigraphically continuous from 0 to ~130 m and 150-190 m core composite depth below seafloor (CCSF). From ~130 m to 150 m CCSF, poor recovery associated with the change to XCB coring prevented the generation of a continuous splice. Magnetic susceptibility, which showed clear, correlative cycles, was used for correlation and splice construction from 0 to 130 m CCSF. NGR was most useful for correlation below ~130 m CCSF, where magnetic susceptibility data was noisy as a result of drilling disturbance associated with numerous chert layers. The chert associated with the Paleocene-Eocene boundary was recovered in Cores U1409A-20X and U1409B-18X, and the boundary appears to fall in the core catcher of Core U1409C-21X. However, physical properties in the interval preceding the PETM appear quite different in Hole U1409C compared to Holes U1409A and U1409B.

Headspace methane concentrations (1.79–6.43 ppmv) were not above atmospheric levels. Interstitial pore water profiles display evidence of compartmentalization with pronounced abrupt downhole shifts in magnesium, manganese, and potassium at ~125-130 m CSF-A suggesting that the unrecovered sequence of cherts acts as an aquiclude. Overall, interstitial pore water profiles of potassium, calcium, and magnesium are consistent with those resulting from exchange with and alteration of basaltic basement at depth. Potassium and magnesium concentrations decrease and calcium concentrations increase with depth. The downhole patterns of manganese and sulfate suggest two zones of organic matter degradation within the recovered sequence, one above the chert-rich interval and one below. In general, sulfate concentrations are high, consistent with low total organic content (TOC). A broad downhole peak in boron concentrations at 59 m CSF-A presumably indicates increased supply from the terrigenous sediment component in lithostratigraphic Unit II.

Carbonate content in the whole sediment column at Site U1409 ranges from 0% to 93%. As with other sites drilled to date on the Southeast Newfoundland Ridge (Sites U1407 and U1408), the most prominent change is a downhole step increase (50 to 90 wt%, ~100 m CSF-A) in sediments of NP14 age (around the Early to Middle Eocene boundary). This step correlates with shifts in several proxies (e.g., color reflectance, magnetic susceptibility, NGR, TOC and TN values) and marks a transition from pelagic chalk sedimentation to clay deposition in the initial stages of sediment drift development. Middle Eocene sediments appear cyclic, with alternating green clay-rich beds and white nannofossil ooze layers having carbonate contents of 40% and 85%, respectively. TOC values are typically 0.1%–0.5% throughout the sediment column. Organic matter is thermally immature and relatively well preserved with low T_{max} values (380°-420°C). Organic matter is a mixture of Type II (algal and microbial) and Type III (land plant/detrital) kerogen.