IODP Expedition 342: Paleogene Newfoundland Sediment Drifts
Site U1407 Summary

Background and Objectives

Site U1407 (proposed site SENR-20A; 41° 25.5'N, 49° 48.8'W) is a mid-depth site (3073 m; ~2600 m paleodepth at 50 Ma, Tucholke and Vogt, 1979), in the upper end of the Expedition 342 Paleogene Newfoundland Sediment Drifts depth transect. The site is positioned to capture a record of sedimentation around 1.9 km shallower than the largely sub-carbonate compensation depth record drilled at IODP Site U1403. The location above the average late Paleogene carbonate compensation depth 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. Our primary scientific objectives for drilling Site U1407 were as follows: (1) to reconstruct the mid-depth CCD in a primarily carbonate-dominated record for the Early and Middle Eocene, (2) to obtain records of the Eocene and Paleocene in carbonate-rich sediments that host abundant foraminifers suitable to the construction of geochemical climate records, (3) to evaluate the history of deep water on sediment chemistry, grain-size and provenance, and (4) to evaluate biological evolution during Paleogene climate transitions. Secondary objectives included dating acoustic horizons to better constrain regional sedimentation during the Paleogene and Cretaceous and allow us to anticipate the likely age of the sedimentary sequence at the remaining Expedition 342 sites.

Principal Results

After a 120 nmi, 11-hour transit from Site U1406 at a speed of 10.9 knots, the vessel arrived at Site U1407 (proposed site SENR-20A) at 0800 h (UTC-2.5h) on 7 July 2012. The plan for Site U1407 called for three holes to a depth of ~250 m drilling depth below seafloor (DSF). A mudline core established water depth for Hole U1407A at 3073.1 m. Cores U1407A-1H through 15H were retrieved using non-magnetic core barrels and the FLEXIT core orientation tool. The first partial stroke was experienced with Core U1407A-11H and the APC system was advanced by

recovery to Core U1407A-15H at 121.9 m DSF. The XCB system was deployed for Cores U1407A-16X through 35X to a final depth of 308.7 m DSF. Overall core recovery for Hole U1407A was 205.64 m for the 308.7 m cored (66%). This relatively low recovery can most likely be attributed to the high heave and large pitch and roll of the vessel during coring operations.

The vessel was offset 20 m to the east and Cores U1407B-1H through 11H were recovered using non-magnetic core barrels and the FLEXIT core orientation tool. A 3-m interval (27.4-30.4 m DSF) was drilled without coring in an attempt to cover a coring gap in Hole U1407A. Based on the recovery of an interval of chert layers in Hole U1407A, the interval from 95 to 127 m DSF was drilled without coring using the XCB system. Cores U1407B-13X through 28X were then recovered to the final depth of 276.3 m DSF. The recovery for Hole U1407B was 234.54 m over the 241.3 m cored (97%).

The vessel was offset 40 m to the west and Cores U1407C-1H through 11H (0-93.0 m DSF) were recovered using non-magnetic core barrels. A 3-m interval (27.4-30.4 m DSF) was drilled without coring to optimize core overlap in multiple holes. Once again, a 21-m interval (96-117 m DSF) was drilled without coring through the chert layers using the XCB. Cores U1407B-13X through 29X were then recovered to the final depth of 261.6 m DSF. Overall recovery for Hole U1407C was 244.4 m from the 237.6 m interval cored (103%). The rig was secured for a dynamic positioning move to the next site at 1915 h on 11 July, ending Site U1407. The overall recovery for Site U1407 was 87%. The total time spent on Site U1407 was 107.25 hours or 4.5 days.

The downhole sedimentary sequence at Site U1407 consists of a Pleistocene to uppermost Lower Cretaceous column of pelagic sediments overlying reef sediments of Late Albian age. The sequence is divided into six lithostratigraphic units. Unit I is ~8 m thick, and composed of Pleistocene foraminiferal nannofossil ooze intermittently interbedded, at the decimeter scale, with foraminiferal sand and clay with nannofossils. Rock fragments of pebble- to cobble-size and coarse silt- to sand-sized quartz and amphibole are pervasive. Unit II is a ~10 m thick sequence of Early Oligocene age composed of clay with nannofossils with disseminated manganese

nodules and sulfide patches and intercalated millimeter to centimeter sulfide layers. Unit III consists of ~70 m of Middle Eocene nannofossil ooze with foraminifers; sulfide patches and layers are also present. An abrupt downhole change in color from light greenish gray into white marks the contact between Units III and IV and is associated with significant changes in physical proxies and a downhole increase in carbonate content. Unit IV consists of ~20 m of Lower Eocene nannofossil ooze with foraminifers. Unit V is composed of Paleocene to Cenomanian nannofossil chalk, which is divided into two subunits (Subunits Va and Vb). The contact between lithostratigraphic Units IV and Va was not recovered because of the operations decision to drill without attempting to recover a sequence interpreted to contain well-developed cherts. Subunit Va is composed of ~60 m of Paleocene nannofossil chalk with foraminifers and radiolarians. Subunit Vb is mainly nannofossil chalk or nannofossil chalk with foraminifers, and spans the Cenomanian to Campanian over a ~85 m-thick sequence. Subunit Vb contains black shales of the Cenomanian-Turonian boundary age (Oceanic Anoxic Event-2, OAE-2, ~93 Ma). Unit VI is divided into two subunits (Units VIa and VIb). Subunit VIa is ~1 m thick and comprises fine-grained, partially silicified and dolomitized calcareous grainstone with horizontal laminations; it is of Late Albian age. Subunit VIb consists of extremely poorly recovered fossiliferous reef deposits of Albian age.

The biochronology of Site U1407 is based on nannofossils and planktic and benthic foraminifers throughout the ~300-m thick sequence. Nannofossils, planktic foraminifers and smaller benthic foraminifers are present in all but the basal Albian neritic limestone, which contains larger benthic foraminifers and macrofossils. Thin Pleistocene and lower Oligocene intervals overlie an expanded middle Eocene through upper Albian succession. A detailed biozonation of Upper to mid-Cretaceous sediments reveals a condensed sequence that records the Campanian/Santonian, Santonian/Coniacian, Coniacian/Turonian and Albian/Cenomanian boundaries. Biostratigraphy of black shale recovered at ~230 m core depth below seafloor (CSF-A) indicates the presence of Turonian nannofossil Zone UC6 above, and Cenomanian nannofossil Zone UC5/4 below, providing strong evidence that this lithology represents OAE-2. Benthic foraminiferal assemblages support this conclusion, with the black shale dominated by agglutinated species and calcareous taxa that indicate

low oxygen concentrations at the seafloor. Radiolarians are abundant and well preserved in the early middle Eocene and in the Paleocene but are either absent or age-indeterminate in both the upper Pleistocene-late middle Eocene and lowermost Paleocene-Cretaceous intervals.

A series of distinct magnetochrons have been identified between Cores U1407A-6H and 10H (and correlative intervals in Holes U1407B and U1407C) that have a biochronology consistent with Chron C20r through Chron C22r (~43.4-49.4 Ma). The magnetostratigraphy and biochronology suggest that sedimentation rates varied between 2.0 and 8.7 cm/ky across the Late to Middle Eocene transition. The Chron C25r-C26n boundary is present in Section U1407A-19X-2.

Headspace methane concentrations (1.4 to 4.12 ppmv) were not above atmospheric levels. Interstitial porewater profiles show evidence of compartmentalization with prominent abrupt downhole shifts, in Mg, Mn and K at ~100-120 m CSF-A suggesting that the unrecovered sequence of cherts acts as an aquiclude. The downhole profile for Mg shows a reversed gradient to the base of the sediment column suggestive of a source of Mg within the highly porous underlying reefal sediments. Carbonate content in the whole sediment column at Site U1407 ranges from 0% to 93%. The most prominent change in carbonate content is a step increase associated with the transition downhole from Middle Eocene to Lower Eocene sediments (59.0 to 82.5 wt% $CaCO_3$, ~80 m CSF-A); this step correlates with shifts in several proxies (e.g., color reflectance, magnetic susceptibility, NGR, TOC and TN values). TOC values are typically 0.1%–0.5% over this whole interval. Homogenous to micro-laminated, organic-rich black shales from Holes U1407A and U1407C are rich in TOC (~4 and 17 wt%). Organic matter is thermally immature and relatively well preserved, as shown by both the high hydrogen indices (~600-620 mg hydrocarbons per g organic carbon) and low T_{max} values (<415˚C). C/N ratios increase as organic carbon concentrations increase. Organic matter is Type II kerogen, derived from algal and microbial primary production.

Sediment bulk density shows a downhole increasing trend from ~1.5 g/cm^3 at the top of the hole to ~2.2 g/cm^3 at the contact between the basal Albian pelagic sediments and the lithified cap of the underlying reef carbonate sediments (~270 m CSF-A).

Grain density peaks at the same contact to 2.9 g/cm^3 in Hole U1407A. Porosity values are generally highest in the upper ~50 m CSF-A of the sediment column and between ~150 and 175 m CSF-A (~60%) whereas porosity is low in the basal pelagic carbonates (~40%). Magnetic susceptibility measurements decrease from high values (up to 120 instrument units, IU) to 5 IU associated with the downhole transition from the thin veneer of Oligo-Pleistocene sediments into the underlying Eocene nannofossil oozes. P-wave velocity increases progressively downhole and shows abrupt changes at ~180, 206, 225 and 270 m CSF-A. These changes in P-wave velocity may contribute to development of weak reflections in the seismic reflection profiles crossing the site. NGR shows an overall downhole increase at Site U1407 with multiple superimposed prominent features that are readily correlated among all three holes: a sharp peak (to ~50 cps, ~10 m CSF-A) at the contact between the Pleistocene cover at the top of the sediment column and the underlying Oligocene clays, a downhole step decrease from ~30 to 5 cps (~80 m CSF-A) associated with the step increase in carbonate content across the contact between the Middle and Lower Eocene nannofossil oozes, and a distinctive peak (to ~40-50 cps, ~230 m CSF-A) associated with the Cenomanian-Turonian black shales. Color reflectance follows a similar trend to magnetic susceptibility with distinctive peaks in a* and b* and a minimum associated with the black shale sequence that can be correlated among all three holes.

The stratigraphic splice constructed for Site U1407 is stratigraphically continuous from 0 to ~112 m core composite depth below seafloor (CCSF) and ~200 to 312 m CCSF. Part of the gap between these two spliced intervals (~112 to 133 m CCSF) is attributable to the operations decision to drill without attempting to recover a horizon with well-developed cherts. The interval between 133 and 200 m CCSF is characterized by modest changes in physical properties data sets and proved impossible to splice using shipboard data alone. Both magnetic susceptibility and NGR were used for stratigraphic correlation and construction of the two spliced intervals. These two data sets show clear, correlative features throughout the sediment column. NGR is the most useful data set for correlation from 0 to ~112 m CCSF and magnetic susceptibility is most useful from ~135 to 200 m CCSF, while both data series show distinctive features from ~200 to 312 m CCSF. The black shale sequence associated with Oceanic Anoxic Event 2 was successfully recovered in all three holes,

although the exact lithostratigraphic expression of this interval differs quite markedly among the three holes.