IODP Expedition 349: South China Sea Tectonics
Site U1435 Summary

Background and Objectives

Coring at Site U1435 (proposed site SCS-6C) became a high priority after failing to achieve our basement objectives at Site U1432 when the final cementing operations compromised the reentry system. This site was originally added as an alternate because of the risk of being unable to reach basement at Site U1432 (proposed site SCS-6A), which required approximately 1900 m of penetration to reach the target depth.

Site U1435 is located on a structural high at the transition between the extended continental crust and the oceanic crust. Similar conspicuous structural high features can be found on the continent-ocean boundary in many other seismic profiles crossing the South China Sea northern margin and therefore appear to represent tectonic structures typical of the area. Since operations time for the expedition ran out before coring reached the basement, the true lithology and formation mechanism of this structural high is still speculative; it could be a volcanic extrusion associated with continental extension at the onset of seafloor spreading, lower crust material emplaced from preferential lower crust extension, exhumed mantle material, or a structural high composed of older (Mesozoic) sedimentary rocks. Coring at this location was designed to help pinpoint the exact nature of this structure and improve our understanding of early continental breakup, the rift-to-drift transition, and seafloor spreading processes.

Operations

After a 336 nmi transit from Site U1434 averaging 8.5 kt, the vessel stabilized over Site U1435 at 1524 h (UTC + 8 h) on 24 March 2014. Since we anticipated shallow sediment cover (~10 m), we conducted a 3.5 khz sonar survey to select a location with maximum sediment thickness to help stabilize the drill string when trying to initiate a hole in basement with thin sediment cover in rough weather. After reaching basement, the plan was to core as deeply into basement as time permitted. Sediment thickness was significantly deeper than expected based on the seismic interpretation. Hole U1435A was cored with the rotary core barrel (RCB) system to 300.0 mbsf when time allocated to the expedition expired, never reaching igneous basement. The RCB system was deployed 32 times, recovering 171.37 m of core over 300.0 m of penetration (57%).

Principal Results

The cored section at Site U1435 is divided into three sedimentary lithostratigraphic units. Unit I (0–77.65 mbsf) is a sequence of Pleistocene–Oligocene greenish gray nannofossil-rich clay and clayey nannofossil ooze, together with manganese nodules. The unit is subdivided into Subunit IA and Subunit IB based on variations in the nannofossil content of the sediment. Subunit IA (0–36.04 mbsf) is Pleistocene to Miocene in age and consists of manganese nodules underlain by clayey nannofossil ooze. The manganese nodules have a lobate appearance and are typically associated with very low sedimentation rates. The massive clayey nannofossil ooze has a few *Planolites* trace fossils visible on the cut surface of the core. Subunit IB (36.04–77.65 mbsf) is Oligocene in age and consists of mostly greenish gray nannofossil-rich clay and lesser quantities of greenish gray clay. There are interbedded silty clay and clay with silt intervals, but deeper in the section the sediment becomes more calcareous, primarily through an increase in the proportion of nannofossils. The sediment is heavily bioturbated with trace fossils of the *Nereites* ichnofacies.

Unit II (77.65–275.54 mbsf) is a 197.89 m thick sequence of pre-Oligocene thick bedded and mostly medium-grained dark gray silty sandstone, with very little carbonate and minor sandy siltstone and conglomerate. The sandstone is better cemented than the Unit I nannofossil-rich clay, and increases in lithification downhole. Units I and II are separated by a hard carbonate rock that might represent a hiatus. The sandstone is moderately well sorted and is characterized by dispersed carbon fragments, shell fragments, and current lamination that is largely disrupted by bioturbation, with burrows typical of the *Cruziana* ichnofacies indicative of shallow marine conditions. Several whole bivalves and gastropods occur in the sandstone. Unit III (275.54–300.00 mbsf) is a 24.46 m thick sequence of dark gray silty sandstone, silty mudstone, and minor conglomerate. The unit is distinguished from Unit II by being generally finer-grained.

We analyzed all core catcher samples and additional samples from split cores for calcareous nannofossils, foraminifers, and radiolarians at Site U1435. Based on nine nannofossil and four planktonic foraminifer bioevents, the sedimentary sequence above 77.65 mbsf is assigned an age spanning the Early Oligocene (<33.43 Ma) to the Pleistocene (>0.12 Ma), with possible unconformities or condensed sections existing between the upper Oligocene and middle Miocene, between the upper Miocene and lower

Pliocene, and between the upper Pliocene and Middle Pleistocene. Based on a limited number of bioevents, sedimentation rates during the Oligocene were around 0.5 cm/k.y.

Samples from 77.65 to 300 mbsf are barren of nannofossils, radiolarians, and planktonic foraminifers. A few long ranging, shallow water benthic foraminifers occur in samples from ~200–250 mbsf. Although these specimens are not useful for age control, they indicate a depositional environment of brackish water to shallow marine for Unit II.

A small number of deformation structures are present in the sedimentary rocks of Site U1435. Most of the fractures are drilling induced, and in the dark grey mudstones near the base of the section, these induced fractures developed along the bedding. Two normal fault structures are found in the sandstone, each composed of several fractures that have little offset. No deformation or thickness changes occur in the rocks of the hanging walls and footwalls, indicating that these faults occurred at a later stage and did not control sedimentation. One linear white carbonate vein was found in the sandstone. Bedding is generally horizontal or sub-horizontal in Unit I but toward the base of Unit II and Unit III the strata are inclined to a significant degree (>25˚). These dips are not depositional and are interpreted to reflect rotation due to normal faulting, possibly during formation of the structural high on which the site is located.

Downhole interstitial water concentrations of chloride, bromide, and sodium are variable and slightly higher than modern seawater; however, the Na/Cl ratio is ~0.85 throughout the sampled interval, which indicates that the interstitial water is of typical marine origin. Only very low concentrations (<10 ppmv) of methane and ethane were detected in the headspace gas samples from Hole U1435A. The $CaCO_3$ content in the upper part of the hole is higher than that of the lower part, which corresponds to the change from nannofossil ooze and nannofossil-rich clay in lithostratigraphic Unit I to sandstone in Unit II. Despite variable total organic carbon (TOC) with depth, the ratio of the TOC to the total nitrogen (C/N) suggests that the TOC is dominated by a terrestrial organic matter source, with lower input from marine organic matter.

We collected twenty-five whole-round samples for microbiological analyses from 37 to 299 mbsf in Hole U1435A. These samples were collected adjacent to samples for interstitial water measurements so that microbiological data and water chemistry data are proximal to each other. The whole-round samples were preserved for shore-based

characterization of the microbial communities (i.e., DNA, RNA, lipids, and cultivation-based studies).

We also collected samples for measuring contamination testing tracers, including microspheres and fluid community tracers. Microsphere tracers placed in the RCB core catcher for Cores 349-U1435-5R through 32R (37 to 299 mbsf). Two microsphere samples were taken from each of the cores collected between those depth intervals: one from scrapings of the core surface and one as a subsample from the interior of each sample. Microscopic counts of the microspheres in these samples will be performed in shore-based labs. Five fluid community tracer (FCT) samples were collected from drilling fluids that drained from the core liners when cores arrived on the catwalk or from a sampling port near the mud pumps on the rig floor during active coring. The fluids collected for FCT samples correspond to cores obtained from depths ranging between 90 and 273 mbsf. Microbial community DNA and lipids from FCT samples will be compared to the same measurements made on the core samples to determine if the drilling fluids contain microbes that can be regularly tracked as recognizable contaminant taxa.

We performed measurements of natural remanent magnetization (NRM) on all archive half cores from Hole U1435A. We subjected these cores to alternating-field (AF) demagnetization up to 20 mT in order to establish a reliable magnetostratigraphy at the site and to observe the magnetic properties of the different lithologies recovered. Due to time constraints, we were unable to perform measurements and demagnetization on discrete samples taken from the working halves. Overall, the paleomagnetic data at Site U1435 are reasonably robust and provide magnetic information about the recovered sediments. Several relatively well-defined polarity intervals are identified, despite some samples showing unstable and ambiguous magnetization. Based on biostratigraphic data, we were able to tentatively correlate certain parts of the magnetic polarity interval recorded in the sediments with the geomagnetic polarity timescale. Assuming no significant hiatus between the marine Oligocene nannofossil-rich clay (Subunit IB) and the sandstone of Unit II, the Chron C16n/C15r boundary (36.05 Ma) is tentatively placed at ~280 mbsf. This interpretation indicates relatively high sedimentation rates for the sandstones of Unit II (~5 cm/k.y.).

Cores from Hole U1435A were measured for physical properties on whole-round cores, split cores, and discrete samples. Thermal conductivity was measured with a needle probe in soft sediments, and then with a contact probe in the sedimentary rocks. The physical properties correlate with lithology and observed lithification. The *P*-wave velocity increases gradually with depth over the first 150 mbsf, whereas the porosity measured on discrete samples decreases from 65% to 30% over the same depth range, reflecting sediment compaction. The bulk density, natural gamma radiation (NGR), magnetic susceptibility (MS), and thermal conductivity show a sharp increase near 78 mbsf at the lithostratigraphic Unit I/II boundary between the nannofossil-rich clay and the sandstone. A significant increase in *P*-wave velocity and thermal conductivity is observed near 170 mbsf, which is associated with stronger lithification of the sandstone. MS and NGR values decrease with depth below 270 mbsf, which corresponds to the change from a dominance of sandstone in Unit II to mudstone in Unit III.