

IODP Expedition 349: South China Sea Tectonics

Week 8 Report (15–21 March 2014)

Operations

Week 8 of Expedition 349 (South China Sea Tectonics) began while cutting Core U1433B-57R and continued through Core U1433B-75R to 5249.1 mbrf (858.5 mbsf). Core U1433B-65R encountered basaltic basement at 786.3 mbsf. Basement coring continued until 2100 h on 17 March when Core U1433B-75R reached a total depth (TD) of 858.5 mbsf. We started cutting half cores with Core U1433B-67R in an attempt to improve core recovery. Basement penetration rates varied between 0.9 and 3.9 m/h. In Hole U1433B, we cut 74 RCB cores from a 672.4 m interval and recovered 443.04 m of core (66% recovery).

After pumping a 50 barrel high viscosity mud sweep, a short wiper trip was made from TD to just above the basement contact (786.3 mbsf) with the top drive installed. While tripping back to the bottom, the hole had to be reamed from 847.4 to 858.5 mbsf. We then pumped another 50 barrel mud sweep to further clean the hole. Our next step was to release the bit in the bottom of the hole so we could log. The rotary shifting tool (RST) was picked up and run in the hole (RIH). An attempt was made to engage the sleeve in the mechanical bit release (MBR). After being unable to engage the shifting sleeve, the RST was retrieved to the surface. Examination at the surface revealed that the RST did not come back with the core line sinker bars. An overshot (fishing tool) was made up and lowered into the hole to fish for the RST. After securing the RST tool, the MBR sleeve was engaged and the bit dropped from the drill string. The RST tool also dropped off the fishing tool on release, leaving the RST tool in the bottom of the hole. The core line was pulled back to surface and the RST tool for shifting the sleeve back into the original position was deployed. With the bit released, the drill string was raised up to 5196.3 mbrf (805.7 mbsf) with the top drive. The top drive was then set back and the drill string raised up to 5079.7 mbrf (689.1 mbsf). The circulating head was picked up and the hole displaced from 689.1 mbsf to the seafloor with 10.5 ppg high viscosity mud intended to improve logging conditions. The drill string was then raised up and spaced out so that the end of the pipe was at 4490.7 mbrf (100.1 mbsf) for logging operations.

After holding a logging safety meeting for rig floor personnel, the triple combo logging tool string was rigged up and deployed. It reached a total depth of 5236.0 mbrf (845.4 mbsf) on 18 March. The hole was then logged and the tool string pulled to surface and rigged down. After rigging down the triple combo tool string, the FMS-sonic tool string was rigged up and deployed to 5233.0 mbrf (842.4 mbsf). The basement section of the hole was logged five times with three passes with the calipers open. On the last pass, the tool become stuck, but was eventually worked free. The rest of the open hole was logged up to the end of the drill pipe and the tool string was then pulled to the surface and rigged down. All logging equipment was rigged down by 1300 h

on 19 March. The drill string and bottom hole assembly (BHA) were recovered and we were secured for transit at 2300 h on 19 March. Total time spent on Hole U1433B was 211.5 h.

After an 18 nmi transit lasting 2 h, the vessel arrived at Site U1434 (proposed site SCS-4E) and switched into dynamic positioning (DP) mode at 0048 h on 20 March. At 0110 h an acoustic positioning beacon was deployed. An RCB BHA was assembled with a new RCB C-7 bit. The core barrels were spaced out at the surface and the 172.07 m BHA was assembled. The BHA was RIH to 4000.9 mbrf and the top drive picked up and spaced out to 4020.0 mbrf to spud Hole U1434A. A center bit was dropped and pumped to land out in the bit. Hole U1434A was spudded at 1215 h on 20 March. The depth of the seafloor was determined to be 4020.4 mbrf by tagging the seafloor with the drill bit. Hole U1434A was advanced by drilling without coring from the seafloor to 4217.4 mbrf (197.0 mbsf) over a 10 h period. The center bit was recovered and a core barrel dropped to start continuous RCB coring. At the end of Week 8, we had recovered Cores U1434A-2R to -12R which extended from 197.0 to 298.1 mbsf (4318.5 mbrf). Microspheres were deployed in each RCB core catcher. Core U1434A-10R was the first core to recover basalt with the sediment/basement interface occurring at ~280 mbsf.

Science Results

Site U1433

The sedimentology group continued to describe cores from Hole U1433B using a combination of visual core description (VCD), microscope inspection of smear slides, core imaging, and scanning for color spectra and magnetic susceptibility. We subdivided Unit II into two subunits: IIA and IIB. Unit II is dominated by dark greenish gray clay with frequent graded interbeds of nannofossil ooze and chalk with sharp, erosive bases and gradational, bioturbated tops. Subunit IIB has proportionally more carbonate than Subunit IIA and the carbonate beds are occasionally substantially thicker, up to several meters. The lowermost sedimentary unit at this site is Unit III, which consists of a sequence of reddish brown or yellowish brown massive claystone and claystone with silt.

The biostratigraphy group finished analyzing samples from Hole U1433B. The results indicate that the sedimentary succession recovered at Site U1433 spans the lower Miocene to the Pleistocene. In addition, calcareous nannofossils in baked sediments recovered between basalt pillows are Oligocene to early Miocene in age, but it is unclear if these fossils are reworked or in situ. The calibrated biohorizons recognized at Site U1433 indicate large variations in sedimentation rates: extremely low (<0.5 cm/k.y.) rates during the early middle Miocene, increasing to between ~5 and ~9 cm/k.y. during the late Miocene to Early Pleistocene, and then increasing to ~20 cm/k.y. during the last 1 Ma.

The igneous petrology and alteration group described the basalts recovered in lithostratigraphic Unit IV of Hole U1433B, which are divided into 45 igneous lithologic units. The basement at this site consists of a 37.5 m thick succession of small pillow basalt lava flows in the top, with a 23.3 m series of massive basalt flows toward the bottom. The pillow basalts are sparsely to highly plagioclase-phyric basalts with a trace of microphenocrysts. Most are nonvesicular to sparsely vesicular and range in grain size from crypto- to microcrystalline. Inter-pillow hyaloclastite breccias with remnants of baked sediments were encountered in two intervals. Downhole the basement is characterized by more massive basalt flows up to ~12.8 m in thickness that range from sparsely to highly plagioclase-phyric with minor microphenocrysts of olivine. Grain size increases to fine- to medium-grained within the interiors of the thickest flows. The basalt ranges from mostly fresh/less altered to moderately altered in intensity, typically as halos in association with cracks and veins, and from gray to dark gray green and yellow to red brown in color. The background of the basement basalt is mostly fresh to slightly altered, and the most widespread alteration occurs near the veins as halos. Alteration veins are abundant in the top of the basement cores and decrease with depth, indicating limited downwelling fluid flow, which is also consistent with fewer fractures that occur with increasing depth. Vein filling minerals include carbonate, celadonite, Fe-oxide/hydroxides, saponite, smectite, and quartz.

The structural geologists measured 240 fractures and veins in the basalt of Hole U1433B. Most of the fractures occur along existing veins without either obvious offset or striations on the surfaces, indicative of drilling-induced fractures, whereas natural fractures are quite rare. In general the veins can be separated into four types with different shapes: single linear, triple-junction, branched, and crosscutting. Arched, crosscutting, and triple-junction veins are usually distributed in pillow basalt layers, whereas single linear, branched, or sinuous veins are usually in the massive flows. The highest frequency of veins occurs in the pillow basalts, whereas there are fewer veins within the massive flows. Alteration along fractures and veins produced 1–2 cm wide yellow to brown colored halos.

The geochemists continued measurements on samples from Hole U1433B. Methane concentrations decreased from ~5250 ppmv to 1050 ppmv over the cored interval. Carbon and CaCO₃ measurements for Site U1433 were also completed. Total organic carbon (TOC) varies from 0 to 1.0 wt%, with a general decrease downhole. CaCO₃ content ranges from 0.5 to 77.8 wt%, with the lowest values (generally <15%) in the upper 300 m of the site. Intervals with higher CaCO₃ content below 300 mbsf correspond to carbonate turbidite layers in lithostratigraphic Unit II. Peaks in TOC and the total organic carbon to total nitrogen (C/N) ratio at ~450 mbsf and 540–590 mbsf could reflect an influx of terrestrial organic matter; however, additional shore-based work is needed to confirm this interpretation. Inductively coupled plasma-atomic emission spectroscopy (ICP-AES) measurements were also completed on basalt samples from Hole U1433B. The loss on ignition (LOI) was very low for all samples, indicating less alteration. These basalts also have higher SiO₂ content than the basalts at Site U1431, whereas the K₂O content is very low at both sites. The geochemical composition of the Site U1433 basalts is consistent with Indian Ocean mid-ocean ridge basalt.

The microbiologists collected additional whole-round and split core samples from Hole U1433B for microbiological analysis. Seven samples were taken from the basalt basement, some of which were very massive with low porosity. These samples showed no evidence of fractures and may be impermeable to microbial colonization. Estimates of the geothermal gradient for Site U1433 based on downhole temperatures made by the advanced piston corer temperature tool (APCT-3) suggest that temperatures at the bottom of the hole are approximately 70°C, which is still permissible for microbial survival.

The paleomagnetists finished measuring archive half cores from Hole U1433B using the cryogenic magnetometer and also conducted alternating field (AF) demagnetization on representative discrete samples. The overall magnetostratigraphy for Hole U1433B is constrained by biostratigraphy. All together, six major positive chrons are recognized. The basal boundaries for the Matuyama chron (2.581 Ma), Gauss chron (3.596), and Gilbert chron (6.066 Ma) are placed at ~350 mbsf, 420 mbsf, and 550 mbsf, respectively. The basal age for sediments in Core U1433B-60R is ~11 Ma. Paleomagnetic results for the basalt units show that the upper part of the basement (805–817 mbsf) is dominated by a positive polarity. Between ~817–830 mbsf, a well-defined reversed polarity zone is observed. Below this depth range, the paleomagnetic inclinations display both normal and reversed polarities.

The physical property specialists completed measurements on whole-round cores, split cores, and discrete samples from Site U1433. The physical properties correlate well with lithology, composition, and observed lithification. The bulk density, *P*-wave velocity, shear strength, natural gamma radiation (NGR), and thermal conductivity increase gradually with depth over the first 150 mbsf, whereas the porosity measured on discrete samples decreases from 90% to 50% over the same depth range. This indicates that sediment compaction dominates physical property variations above 150 mbsf. Below 240 mbsf, variability in porosity, magnetic susceptibility (MS), and NGR values reflects interbedding of carbonate and clay layers. An increase in *P*-wave velocity from ~1700 to ~2000 m/s near 550 mbsf coincides with stronger lithification in the deeper sediments. From 680 to 750 mbsf, *P*-wave velocities measured in the lithified carbonates reach ~2600 m/s, showing a strong contrast with those measured in the clay (~2000 m/s). The strong reflectors observed in the seismic profile from this site probably result from this contrast in velocity. The clays from 750 to 800 mbsf show a gradual increase in MS and decrease in NGR. The basalts below 800 mbsf display very low NGR and porosity, and variable MS. Some of the fresh, phenocryst-rich basalts have very high MS and *P*-wave velocities.

The modified triple combo and FMS-sonic tool strings were run in Hole U1433B on 18 and 19 March. Both tool strings reached 830 m wireline depth below seafloor (WSF), about 18 m above the bottom of the hole. Between 100–550 m WSF, there were rapid variations in borehole diameter from ~25 cm to wider than 43 cm. Below 550 m WSF, the hole diameter tended to be in gauge, with fewer washed out zones. There is a trend of increasing density and sonic velocity from the top of the logs at 100 m WSF down to 750 m WSF due to compaction and cementation with depth. Superimposed on this trend, excursions to higher velocity and photoelectric factor

(PEF) and to lower NGR mark the occurrence of carbonate beds. This information was used to infer lithology in the non-recovered intervals of Hole U1433B. In the red clay (Unit III), from ~750 to 800 m WSF, high values in the PEF log indicate that hematite and other oxides increase in concentration downhole toward the top of the basalt at ~800 m WSF. Pillow basalt, a massive basalt flow, fractures, and veins are seen in the FMS images in the basement.

Site U1434

The lithostratigraphy group described cores from Hole U1434A. They divided the sedimentary sequence into three units. Unit I is composed of interbedded dark greenish gray claystone and dark sandstone with occasional breccia. Unit II contains thick, greenish gray nannofossil-rich claystone with very thin claystone with silt interbeds. Unit III consists of dominantly massive yellowish brown claystone with nannofossil or foraminifer-rich claystone.

Biostratigraphy based on calcareous nannofossils and planktonic foraminifers indicates that the sediment succession recovered at Site U1434 spans the uppermost middle to upper Miocene, with the base of the sequence younger than 11.9 Ma. Calcareous nannofossils are generally common to abundant but decrease in abundance downhole, and preservation is poor to moderate. Planktonic foraminifers vary from common to absent with good to poor preservation, with frequent fragmentation. Radiolarians are absent in most samples, with a few well preserved specimens found in only one sample. Calibrations based mainly on calcareous nannofossil biohorizons indicate a sedimentation rate of ~1.6 cm/k.y. for the sediment sequence recovered at Site U1434.

Geochemical analysis of headspace gas in Hole U1434A indicates very low levels (<3 ppmv) of methane. Other measurements for this site (paleomagnetism, interstitial water geochemistry, and physical properties) were ongoing at the end of the week.

Education and Outreach

We conducted nine ship-to-shore video events with schools, universities, and organizations in China, Spain, Germany, and the United States. In China, we connected with two different groups at Tongji University, speaking with 73 first-year undergraduates during the first event and 250 students during the second event. We also held an event with students at the South China Sea Institute of Oceanology. In the United States, we connected with undergraduate and graduate students at Louisiana State University and the University of South Florida. We also connected with a high school class in Spain. We conducted two workshop events with a Marine Science Symposium for high school students in Massachusetts, United States. We also connected with approximately 600 children and adults that participated in an outreach event that was organized in association with the International Ocean Discovery Program (IODP) and International Continental Scientific Drilling Program (ICDP) annual meeting in Erlangen, Germany.

Technical Support and HSE Activities

The following technical support activities took place:

Laboratory:

- Labs processed cores from Sites U1433 and U1434.
- Thin section lab busy preparing samples from Sites U1433 and U1434.

The following HSE activities took place:

- A boat and fire drill was held on 19 March 2014.