IODP Expedition 350: Izu Bonin Mariana Rear Arc

Week 5 Report (28 April–4 May 2014)

Operations

Hole U1437E

Deployment of the reentry cone and 20.7 m of 20 inch casing for Hole U1437E was completed at 1905 h on 27 April, when the bit cleared the reentry cone. The drill string was retrieved back on the rig floor at 0030 h on 28 April.

A drilling assembly consisting of an 18.5 inch tri-cone bit and an underreamer was made up to drill the hole for the 264 m long, 16 inch casing. The underreamer was set to enlarge the hole to 22 inches, and tested to confirm that the arms opened at a mud pump rate of 25 strokes per minute. The drill string was deployed to the seafloor, followed by deployment of the subsea camera to guide the reentry into Hole U1437E at 1105 h. After the successful reentry, the camera system was retrieved and Hole U1437E was drilled to the target depth of 271.7 mbsf by 0400 h on 29 April. The hole was swept with 60 barrels of high-viscosity mud to remove drill cuttings. The drill string was then raised to 12.7 mbsf and lowered back down to total depth (271.7 mbsf) while circulating seawater to ensure the borehole was clear. No obstruction or fill at the bottom of the hole was detected. Another 60 barrel high-viscosity mud sweep was circulated. The drill string was pulled out of the hole with the bit clearing the seafloor at 0910 h and arriving at the rig floor at 1300 h on 29 April.

The 264 m long 16 inch casing was assembled in an eight-hour effort. The casing running tool was installed and the casing string was lowered to the seafloor by 0145 h on 30 April. The camera system was deployed to guide the reentry into Hole U1437E, which was completed at 0350 h. The casing was lowered into the hole and the top of the casing was latched into the casing hanger in the reentry cone at 0600 h. The latch was verified with 10 klb of pull from the rig.

To ensure the casing will act as the circulation conduit during future coring in Hole U1437E, the bottom of the casing had to be cemented firmly to the formation. With the casing running tool forming a seal at the top of the 16 inch casing, 20 barrels of 14.5 lb/gal cement were mixed and pumped from the rig floor through the drill string and through the 60 m stinger extending from the casing running tool down into the hole. The cement emplacement was followed up with 295.8 barrels of seawater, a volume calculated to displace the cement to the bottom of the casing such that half the cement volume would extend upward between the formation and the base of the casing, and the other half would remain inside the bottom of the casing, to be drilled out later. The cement was in place at 0720 h on 30 April. The casing running tool was released and the drill string and standpipe manifold were flushed clean with seawater. The camera was

retrieved, the top drive was disengaged, and the drill string was tripped to the surface, with the running tool clearing the rig floor at 1220 h on 30 April.

The next operation was to drill out the cement and then a 14.75 inch hole to 1104 mbsf (the total depth of Hole U1437D) for the 10.75 inch casing. After breaking down the running tool and the underreamer assembly, a bottom-hole assembly with a 14.75 inch tri-cone drill bit was installed and the drill string was tripped back to the seafloor. The camera was deployed to guide the reentry into Hole U1437E, which was completed at 2245 h on 30 April, and then was retrieved back to the rig floor. At 0030 h on 1 May, the top drive was picked up and the bit lowered to the bottom of Hole U1437E. At 0330 h, the bit tagged the top of the cement plug at 264.7 mbsf, 1 m below the 16 inch casing shoe. Cement should have been contacted ~10 m above the shoe. This indicated that the cement had been displaced several meters too far down the 16 inch casing and that the casing likely had not been cemented to the formation as planned, thereby requiring a second cementing round trip.

The drill string was pulled back to 230.7 mbsf, the top drive was disengaged, and the drill string was tripped to the surface, clearing the seafloor at 0440 h and arriving at the rig floor at 1030 h on 1 May. The casing running tool and logging bit were made up once more, the drill string was lowered to the seafloor and the subsea camera was deployed to guide reentry into Hole U1437E, which was completed at 1740 h on 1 May. After tripping into the hole to 55.7 mbsf using the top drive, weight was applied through the drill string to ensure the casing running tool sealed the top of the casing in preparation for cement delivery. When circulation was attempted by pumping seawater into the hole and around the bottom of the 16 inch casing, a pressure increase was observed, indicating that the bottom of the casing was actually sealed off, either by the first cementing job or by the formation sealing off around the casing since. The second cementing job was therefore aborted at 1830 h. The drill string was raised to 18.1 mbsf, the top drive disengaged, the camera system retrieved, and the drill string tripped to the surface, clearing the drill floor at 2350 h on 1 May.

The 14.75 inch tri-cone bit was installed again, lowered to the seafloor, and Hole U1437E was reentered for the seventh time at 0605 h on 2 May. The bit was lowered to 230.7 mbsf, the camera used to guide reentry was retrieved, and the top drive was engaged to wash the hole down to 266.7 mbsf, where the cement plug was encountered. The cement plug, which extended to 271.7 mbsf, was drilled out and the hole was flushed with high viscosity mud. By the end of the week, Hole U1437E was drilled (without coring) to ~980 mbsf. When the target depth of 1104 mbsf is reached, installation of the 10.75 inch casing in Hole U1437E will begin.

Science Results

Site U1437

In the absence of new cores since the beginning of this week, core describers have worked on the report for Site U1437. Time was used to correct inconsistencies identified in the DESClogik data capture program and the accompanying graphic summaries for Holes U1437B and U1437D and to further refine the methodology used in macroscopic and microscopic descriptions. We described thin sections and took photomicrographs to be used in the Site U1437 report. Data and preliminary interpretations were shared with other lab groups, and efforts to synthesize lithological observations with physical property and geochemistry data continued.

This week, the core describers grouped the intervals described in Holes U1437B and U1437D into four lithostratigraphic units (Units I through IV), based on changes lithological characteristics. The lithostratigraphic units are distinguished from each other based on the proportion and characteristics of tuffaceous muds and mudstones with interbedded tephra units. The tuffaceous muds and mudstones are strongly to intensely bioturbated. Alteration becomes more pervasive and increases in intensity downhole in both holes; it is initially predominantly glauconitic-smectitic, and eventually becomes more chloritic. Iron sulfides are pervasive throughout both holes, especially as replacements of worm burrows, and according to rock magnetic properties, greigite is progressively replaced by pyrite downhole in Hole U1437D. Compaction of sediment at Site U1437 increases linearly from ~0% above ~410 mbsf to ~36% at the base of Hole U1437D. The transition from unconsolidated to lithified rocks occurred progressively, however, sediments were considered lithified from 427 mbsf (top of Hole U1437D) downward.

Unit I (Interval U1437D-28R-2, 112 cm; 0–682.12 mbsf) includes all of Hole U1437B and ends in Hole U1437D. Unit I is dominated by tuffaceous mud and mudstone (89% of total recovered material) alternating with thin evolved, mafic, and bimodal ash/tuff intervals, and minor lapilli-ash/-tuff intervals. The boundary between Unit I and Unit II is marked by the first appearance of monomictic lapilli-tuff, which is the characteristic lithofacies within Unit II; this change is reflected in the physical properties (e.g., increase in magnetic susceptibility, see below).

Unit II (Interval U1437D-28R-3, 0 cm to 32R-CC, 28 cm; 682.12 to 728.1 mbsf) is 46 m thick and dominated by evolved pumice lapilli-tuff and lapillistone intercalated with evolved tuff. On the basis of uniformly coarse grain size, Unit II is interpreted to record medial or proximal explosive volcanism, possibly in the adjacent rear-arc. Minor (22%) intercalated tuffaceous mudstone indicates brief periods of rear-arc volcanic quiescence during deposition of Unit II. The boundary between Unit II and III is marked by the lowermost occurrence of closely spaced coarse-grained tuffs, and the transition back to dominance of tuffaceous mudstone.

Unit III (Interval U1437D-33R-1, 0 cm to 63R-2, 26 cm; 728.1–1017.8 mbsf) is 270 m thick and consists of tuffaceous mudstone (64%) with intercalated evolved tuff and minor evolved lapilli-

tuff intervals. Near the top of Unit III (Interval U1437D-34R-3, 78 cm to 34R-4, 118 cm) lies a single distinctive 1.5 m thick interval of soft-sediment deformed mudstone intraclasts (up to ~20 cm in size) supported in a matrix of tuffaceous mudstone and volcanic clasts (up to 5 cm). This is interpreted as a submarine debris flow deposit. Unit III shows an increase in fine-grained tuff (relative to tuffaceous mudstone) in its basal ~80 m. The boundary between Unit III and Unit IV is defined by a change downhole to more coarse-grained tuff and pumiceous lapilli-tuff (also mostly evolved); tuffaceous mudstone decreases below this boundary.

Unit IV (Interval U1437D-64R-1, 0 cm to 73R-CC, 5 cm; 1017.18–1096.74 mbsf) extends to the bottom of Hole U1437D and is 80 m thick. It is composed of evolved tuff and lapilli-tuff with rare tuffaceous mudstone.

This week, the chemistry group interpreted data for all interstitial water samples from Site U1437 (n = 67), which were collected to 700 mbsf; below that depth, extracted water volumes were too small. Interstital water analyses include all major and trace components, except ammonium, which is currently being analyzed.

A zone of reduced sulfate and increased alkalinity at shallow depths (0–100 mbsf) is interpreted to record microbial activity dominating pore water chemistry. Sodium concentrations increase gradually downward in this interval, and then increase more abruptly at 450 mbsf. Magnesium is relatively constant to 485 mbsf, where it abruptly decreases before continuously declining to 700 mbsf. Calcium increases gradually from 0 to 700 mbsf. The downward increase in Na and Ca and the decrease in Mg are typically characteristic of volcanic glass alteration.

Recalibration for total carbon and nitrogen analyses (sampled to 340 mbsf in Hole U1437B) was done using a new standard calibration based on the Thermo Fisher Scientific NC Soil Reference Material (2.29 wt% C; 0.21 wt% N). The calibration based on this standard enables more reliable measurements for C and N than in previous attempts (reported in previous weeks) because elemental concentrations in this standard are within the range of those encountered at Site U1437. However, the new standard lacks sulfur, which was therefore excluded from further analysis. Ongoing analyses reveal that total organic carbon (TOC) contents in Site U1437 sediments range from 0.27 to 0.82 wt%, and total nitrogen (TN) contents from 0.005 to 0.05 wt%. Molar TOC/TN ratios range between 11.2 and 72.5 (Samples U1437B-1H-1W, 60–61 cm and 12R-5W, 54–55 cm), indicating a mixed (TOC/TN range 10–20) input of organic matter from marine (TOC/TN = 4–10) and terrestrial (TOC/TN >20) sources between 0.6 and 530 mbsf.

The geochemistry group completed pXRF analysis (n = 30) and ICP-AES major and trace element analyses (n = 30) on samples from Cores U1437B-35X through U1437D-72R (243–1086 mbsf). The group is currently analyzing this data in an effort to determine which tephras are consistent with an arc front or active rift provenance, and which came from the rear arc.

The geochemistry group also shared their experience with pXRF analysis of igneous and sedimentary samples from Expedition 350 with technical staff in two video-recorded

demonstration sessions. Sample preparation and instrumental procedures were recorded to facilitate staff and scientific personnel training on future expeditions.

Eight physical properties (PP) units were differentiated based on (1) distinct offsets in otherwise continuous profiles that define boundaries between intervals, and (2) interval characteristics such as magnitude, rate of change and relative scatter of measurements. Three PP unit boundaries coincide with the lithostratigraphic unit boundaries; the others appear to be related to post-depositional processes that will have to be examined further.

PP unit 1 (0–430 mbsf) is characterized by a downhole increase in bulk density (1.5 to 1.6 g/cm^3) and *P*-wave velocity (1501 to 1848 m/s) and a corresponding downhole decrease in porosity (70–65 vol%). The most significant change that marks the top of PP unit 2 (430–550 mbsf) is an initial increase in porosity (61 to 67 vol%) then a downhole continuation of the decrease observed through PP unit 1. The top of PP Unit 3 (550–682 mbsf) is characterized by a sharp increase in porosity (from 52 to 65 vol%), and corresponding decrease in bulk density (1.8 to 1.6 g/cm^3). This initial offset is followed by more normal downhole trends, similar to those seen in PP unit 2. The color reflectance ratio of a*/b* displays a significant decrease in the scatter of the data, indicating that color is less variable through PP unit 3 than in PP unit 2. The upper boundary of PP unit 4 (682–728 mbsf) corresponds to the lithostratigraphic Unit I/Unit II boundary, and is marked by an increase in the scatter of density and porosity, a significant increase in *P*-wave velocity values and range, an abrupt increase in magnetic susceptibility (MS; average of 476 IU versus 138 IU for PP unit 3) and an abrupt decrease in natural gamma radiation (NGR) from ~20 cps to ~5 cps. The upper boundary of PP unit 5 (728–794 mbsf) corresponds to the lithostratigraphic Unit II/Unit III boundary and is defined by an increase in NGR values to ~16 cps and a decrease in the scatter of *P*-wave velocity, followed downhole by the continuation of the *P*-wave trend observed in PP unit 3. The top of PP unit 6 (794–846 mbsf) is defined by an increase in the scatter of the *P*-wave velocity and color reflectance (a*/b*) values. The top of PP unit 7 (846–1018 mbsf) is marked by an initial ~0.3 g/cm^3 decrease in bulk density and a corresponding increase in porosity (846 to ~860 mbsf), followed by regular trends downhole and marked by significant scatter. The top of this unit is also characterized by an abrupt decrease in the average MS value from 491 IU (PP unit 6) to 167 IU. The upper boundary of PP unit 8 (1018–1097 mbsf) corresponds to the lithostratigraphic Unit III/Unit IV boundary. PP unit 8 is characterized by an increase in the average MS value to 916 IU, and intervals of high (2 W/[m·K]) and intervals of very low (~1 W/[m·K]) thermal conductivity.

Analysis of the remaining discrete samples from Hole U1437D allowed us to verify, and slightly revise, the magnetostratigraphy for the deepest 160 m of Hole U1437D. The base of the Gilbert Chron (C3r) can only be restricted to within a 7.1 m interval (969.56–976.66 mbsf) owing to overprinting and a complex transition. Normal polarity appears to be continuous from this depth to the bottom of the hole, although post-depositional overprinting may be present. Either the sedimentation rate is substantially higher in the deepest 100 m of Hole U1437D, or a hiatus is masking a step progression into a lower polarity interval.

The following datums were confirmed this week: C3n.4n top (4.997 Ma, Interval U1437D-44R-8, 85 cm; 844.22 mbsf); C3n.4n base (5.235 Ma, Interval U1437D-48R-4, 5 cm; 868.4 mbsf); C3An.1n top (6.033 Ma, between Intervals U1437D-58R-8, 26 cm and -59R-5, 81 cm; 969.56–976.66 mbsf).

Partial thermal demagnetization performed on 68 selected samples shows that at least part of the overprinting is carried by a phase that demagnetizes at around 350°C; this is likely to be the magnetic iron sulfide greigite, which decomposes at this temperature and is commonly reported in hemipelagic sediments. Complete thermal demagnetization to 600°C carried out on 12 samples confirmed magnetite as the major carrier of remanence.

The coercivity spectrum of the magnetic mineralogy was determined by partial anhysteretic remanent magnetization experiments on 13 discrete samples. Preliminary results reveal a coercvity peak at 20 mT in most samples, confirming magnetite as the principal magnetic carrier and justifying the use of a relatively low demagnetizing field in the magnetostratigraphic study. Broadening of the spectrum in most samples indicates the presence of a second, higher coercivity magnetic phase, consistent with the presence of magnetic sulfides.

Isothermal remanent magnetization studies on 26 samples again supported the presence of magnetic sulfides, in samples from 37 mbsf downwards, with samples falling into sulfide-rich and sulfide-poor populations. Samples below ~710 mbsf exhibit the lowest concentrations of magnetic sulfides relative to magnetite. Saturation isothermal remanence (SIRM) normalized for susceptibility shows an overall log-linear downhole decrease suggesting gradual conversion of magnetic sulfides to paramagnetic pyrite, but superimposed on this trend are anomalous intervals broadly coinciding with offsets and breaks in slope of the physical properties profiles.

Anisotropy of magnetic susceptibility was measured on 170 discrete samples. This will provide information on magnetic fabric, particularly where this may reflect sediment compaction. Data interpretation is ongoing.

This week, the paleontologists finished examining foraminifer Samples U1437D-60R-CC through U1437D-72R-CC, compiled datasets from Site U1437, worked on the age-depth model for Site U1437 in cooperation with the magnetostratigraphers, and worked on the Site U1437 report as well as revisions of previously written pieces for the Methods and Site U1436 chapters.

Site U1437 recovered a 1100 m thick section of upper Miocene and Pliocene to Recent tuffaceous mud, mudstone and tephras. A 432 m succession spanning the last ~3 m.y. (55 cores) was recovered from Hole U1437B and a 656 m succession (73 cores) spanning the interval ~3–7 Ma was recovered from Hole U1437D. No significant overlap occurred between Holes U1437B and U1437D. Nineteen planktonic foraminifer and 17 calcareous nannofossil biostratigraphic events were identified. Overall, the two groups agree well, particularly in Hole U1437B and in the upper ~600 m interval of Hole U1437D, and biostratigraphic datums are consistent with magnetostratigraphic datums.

Planktonic foraminifer datums in the upper ~600 m of the succession indicate a middle Pliocene to Pleistocene (Zones PL3-PT1b) age. The Pliocene–Pleistocene boundary (2.588 Ma) was placed between 372.07 and 416.32 mbsf based on T (top) *Globoturborotalita decoraperta* in Sample U1437B-53X-CC and T *Globorotalia pseudomiocenica* in Sample U1437B-48X-CC. The planktonic foraminifers in this part of the succession were generally common and showed good to poor preservation, depending on the interval. From 600 to 1100 mbsf, establishing a biochronology proved more challenging due to the number of barren intervals and the poor preservation of fossils. Lithification of samples also hindered foraminifer extraction and examination. Inferred datums in the lower part of the succession still agree reasonably well with magnetostratigraphic datums, but their scarcity resulted in larger uncertainties. Therefore, below ~550 mbsf most of the datums were tentatively assigned, e.g., T and B (bottom) *Globorotalia margaritae* (3.85 ± 0.03 Ma and 6.08 ± 0.03 Ma, respectively), B *Globorotalia crassaformis* sensu lato (5.53 ± 0.04 Ma) and T *Sphaeroidinellopsis kochi* (4.53 ± 0.17 Ma). There was also some evidence of reworking with early–middle Miocene fauna found as high as 322 mbsf but mainly restricted to the interval ~650–1100 mbsf. The benthic foraminifer data (e.g. Stilostomelidae extinction) corroborated the position of the middle Pleistocene transition. Although preliminary, the observed changes in their abundances also confirmed inferences on carbonate preservation made from semi-quantitative planktonic foraminifer abundances and species distribution analyses performed on all samples examined.

Calcareous nannofossils are generally abundant and well preserved throughout Hole U1437B, and in Hole U1437D down to Sample U1437D-26R-CC. In Samples U1437D-27R-CC through 73R-CC, the preservation was generally poor and several samples were barren of nannofossils. Strong signs of overgrowth, particularly in the genus *Discoaster* were seen in this interval. In Hole U1437B, the calcareous nannofossil bioevents showed that the succession spans the early Pleistocene to late Pliocene. From the top of Hole U1437B to 14.6 mbsf the biozone CN15 is recognizable because of B *Emiliania huxleyi* in Sample U1437B-2H-CC. T *Pseudoemiliania lacunosa* (Sample U1437B-6H-5, 75–76 cm) defines the bottom of CN14b. Between 111.70 and 121.27 mbsf the bottom of CN14a could be positioned on the basis of the Tc (top common occurrence) *Reticulofenestra asanoi* (Sample U1437B-15F-3, 80–81 cm), and Bc (bottom common occurrence) *Reticulofenestra asanoi* (Sample U1437B-16F-CC). Bottoms of CN13a, CN12d, CN12c and CN12b were defined by T *Discoaster brouweri* (245 mbsf), T *Discoaster pentaradiatus* (329 mbsf), T *Discoaster surculus* (363 mbsf), and T *Discoaster tamalis* (380 mbsf), respectively. The assemblage in Hole U1437B was dominated mainly by species of the genus *Gephyrocapsa*. In Hole U1437D the succession covers the Pliocene–late Miocene. Preservation strongly deteriorates below Sample U1437D-26R-CC, and several barren samples were detected. T *Reticulofenestra pseudoumbilicus* in Sample U1437D-19R-3, 32 cm, defines the bottom of CN12a at 595 mbsf. The last reliable datum was T *Triquetrorhabdulus rugosus* (Sample U1437D-48R-CC). It was detected despite strong signs of dissolution/overgrowth affecting its preservation.

Fourteen (out of 25) biostratigraphic datums and twenty magnetostratigraphic datums were selected to construct an age-depth relationship for Site U1437 using a linear fit. The model consists of six linear segments, with linear sedimentation rates ranging between 98 m/m.y. to 259 m/m.y. (average 168 m/m.y.). The corresponding total mass accumulation rates fluctuate between 12 to 35 g/cm^2/k.y.

Education and Outreach

A total of 24 education sessions were held this week with schools and colleges from elementary to university level, including the first ever link to an Australian school. New teacher resources on thin sections and petrographic microscopes are being developed this week. Numerous Facebook and Twitter posts and five blogs were completed this week. Photographs of ship activities taken and used for current blogs were placed on file for future use. Interviews have been arranged with various members of the technical staff and the ship's crew.

A videoconference was held with the shore office for feedback and support. We reported the need for some new teacher at sea resources, which will be made available for the next expedition. We reported ongoing issues with Internet connectivity.

Technical Support and HSE Activities

Technicians completed the processing and the analysis of core material sampled last week. While waiting on the resumption of coring, staff performed equipment maintenance, updated their technical reports, and completed mandatory university training.

Laboratory

Thin section preparation and ICP analysis on samples taken the previous week were completed this week.

The curator and selected staff are assisting programmers with developing the specification for an update to the sample entry program SampleMaster.

Design work was completed on the interface and control boards for the stepper motor replacements on the core loggers. Fabrication of boards and testing are planned for Expedition 352.

We are still waiting on vendor software upgrades for the Bathy 2010 system.

Basic electronic classes were held for interested staff and scientists.

Development

Developers, in collaboration with both shore and ship staff, worked on developing software requirements for the following:

- Management of derived tests in our Laboratory Information Management System (LIMS);
- Replacement for our LIMSpeak data presentation application;
- The new Request Code application;
- The new Section Entry (Catwalk Entry) application that will replace some of the Sample Master application's functionality.

Enhancements to the SampleMaster application that were requested by the shipboard curator were completed and will soon be deployed.

Minor issues in Drill Report were completed and will soon be deployed.

Developers supported shipboard technicians on small projects that involved data upload or data cleanup in the DESClogik, ICP, and XRF data sets.

Information Technology

Staff received and installed an updated "signature file" for our firewall that addresses issues with application control. After installation, testing was successful but configuration is still in progress.

Work continues on Cumulus (document management system) to resolve issues importing documents from the shore vault.

We experienced issues with the core laboratory label printer dropping off the network. The issue has been traced to a network port but the cause of the problem is still unknown.

Safety

The weekly fire and boat drill was completed as scheduled.