IODP Expedition 366: Mariana Convergent Margin

Site U1492 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Site U1492 (proposed Site MAF-15A) is located on the summit of Yinazao Seamount (informally called Blue Moon Seamount in previous publications and the Expedition 366 *Scientific Prospectus*) on the Mariana forearc, at 15°42.57′N, 147°10.60′E, in 3666 m of water. The site lies about 1 km NW of multichannel seismic (MCS) reflection profile EW0202 75-78. Site U1492 was chosen to be at an active fluid spring that was observed and sampled with the *Jason-2* remotely operated vehicle (ROV) in 2003 (Fryer et al., 2006; Hulme et al., 2010) on the southwest rim of the slightly flattened summit of the mud volcano.

Yinazao Seamount is a serpentinite mud volcano that lies about 55 km from the trench axis. It is the closest to the trench of the three seamounts cored on this expedition. The subducting slab lies approximately 13 km below its base, based on multichannel seismic data (Oakley, et al., 2007), and the seamount lies on a regional NE trending fault. At the summit of the seamount there is a fault scarp with a maximum throw of about 80 m that lies colinear with the regional NE fault trend. The spring lies at the SW extension of this fault, and the fault may have directed egress of rising fluids to the spring. The possible occurrence of a spring at this locality was suggested by a small patch (about 40 m diameter) of high backscatter on a bathymetry and sidescan sonar image from a 1997 survey using the Hawaii Mapping Research – 1 System aboard the R/V *Thomas G. Thompson*. Reflectors visible on MCS Line 75-78 below the seafloor near/at the summit may be real layering, suggesting different flow units, or may be out-of-plane returns from the foot wall (SE) block of the summit fault.

The plan was to core a small north–south transect of three holes each separated by about 100 m, with the southernmost hole located near the spring itself. Installation of screened casing for future borehole monitoring and sampling experiments was planned for a fourth hole at the central spring area. Drilling at Site U1492 was expected to recover recently erupted serpentinite muds along with serpentinized peridotite clasts and perhaps other lithologies from the conduit system of the seamount. It was also expected to recover pore fluids with the most pristine signal from slab-derived fluids, given the proximity of the spring location. The transect was chosen to:
1) intersect mudflows of variable composition that had emanated from the area near the spring;
2) potentially date discrete mud flows paleontologically, should there be sediment layers between them; 3) determine variability of composition of rock clasts in the mudflows;
4) investigate potential systematic variability in degree of serpentinization (possible lower degrees at initiation of mud volcanism, e.g., conduit “throat clearing”); 5) examine transport conditions of fluids; 6) provide a measure for the scale of potential flow characteristics (e.g., diffuse vs. channelized); 7) determine the composition of fluid from depth; and 8) determine

microbial community interactions at depth and near the sediment surface under a range of flow conditions.

Operations

The ship arrived at Site U1492 (proposed Site MAF-15A) at 0730 h on 18 December after a 9 km transit from Site U1491 in dynamic positioning (DP) mode. Two replacement drill collars and a new advanced piston corer (APC)/extended core barrel (XCB) outer core barrel assembly were made up, to replace those lost in Hole U1491B. The rig mechanic worked on the blower motor in the top drive for 3 h before the remainder of the bottom-hole assembly (BHA) was assembled. The pipe trip to the seafloor began at 1630 h on 18 December. The camera was deployed for a seafloor survey, and the target, a seep marked by a previous ROV survey, was found immediately, so no further survey was required. The ship was offset 200 m to the north, and coring in Hole U1492A started at 0725 h on 19 December, establishing a seafloor depth of 3657 mbsl. After Core U1492A-2H, further coring was conducted using the half-length APC (HLAPC) for better recovery in the stiff serpentinite muds. While recovering Core U1492A-9F from 38.3 mbsf, the core line became snarled in the oil saver due to a kink above the rope socket, most likely caused by the high ship's heave. At this point we ceased coring in the hole, not far short of the 50 mbsf target depth, with 38.3 m cored and 38.5 m recovered. After slipping and cutting the drilling line, the oil saver was cleared of the tangled core line and the core line was reheaded.

Hole U1492B, started at 0045 h on 20 December, was located 100 m south of Hole U1492A and formed the second in the mini-transect of holes at this site. The seafloor depth was 3669.1 mbsl, 12.5 m deeper than at Hole U1492A. Coring continued using the HLAPC coring system through Core U1492B-13F to 51.4 mbsf (52.0 m recovered), completing the objective at this hole.

At 1100 h on 21 December, the ship was offset 120 m south to start Hole U1492C with a seafloor depth of 3666.5 mbsl. HLAPC coring continued through Core U1492C-23F to 98.7 mbsf. Formation temperature measurements (APCT-3) were made during Cores 3F, 6F, 9F, 13F, 16F, 19F, and 22F (9.5, 23.5, 33.6, 51.7, 65.8, 73.9, and 94.0 mbsf, respectively). Coring was suspended at this point to allow deployment of the temperature dual-pressure tool (T2P) on the motion decoupled hydraulic delivery system (MDHDS). The hole was swept with 20 barrels of high viscosity mud while the tools were being rigged up and prepared for deployment on the rig floor. The hole had been stable up to that point with no fill on connections or overpull coming off bottom. It took less than 1 h to rig up the MDHDS/T2P/Electrical Release System (ERS) tools, but while stabbing the logging line through the blocks (without rotation or circulation), the hole became unstable. The line was quickly pulled back out and the driller fought to maintain rotation, with top drive torque increasing from 200 to over 500 A. It was agreed that the T2P deployment should be abandoned for this site and retried at a shallower depth at the next summit drill site (Site U1496, proposed Site MAF-11A). The hole was swept with 20 barrels of high viscosity drilling mud and a wiper trip was made to 70.6 mbsf to try and get some of the dense cuttings either out of the hole or below the bit so they could be ground up to a finer grain size and circulated out of the hole. Coring resumed at 0200 h on 23 December. HLAPC Cores U1492C-24F to 28G were cut to 117.5 mbsf before high torque and overpull necessitated a second wiper trip. The next 13.75 h were spent on hole conditioning before it was considered safe enough to install the sinker bars and recover the XCB wash barrel, which contained “ghost core” U1492C-28G. Coring then proceeded using the XCB coring system to recover Cores U1492C-29X through 30X to 129.4 mbsf. While cutting Core U1492C-31X at 139.1 mbsf, the driller once again lost rotation. The next 2.5 h were spent working to free the pipe; we then decided to abandon further attempts to core Hole U1492C, and the drill pipe was pulled up to the rig floor. We cored 139.1 m and recovered 72.0 m at Hole U1492C.

At 0935 h on 24 December, preparations began for deploying the reentry cone/drill-in casing system for Hole U1492D. The previously assembled standard reentry cone was moved over well center on the moonpool doors. The casing shoe joint and four 39 ft screened casing joints were assembled, followed by 13 additional 10.75 inch casing joints. The casing string was lowered and latched into the reentry cone. The stinger assembly was made up, including a tri-cone bit, Baker-Hughes Inteq high torque mud motor, a set of HOC underreamers, and the Dril-Quip (DQ) running tool. The motor/underreamer combo was tested in the moonpool for proper operation. At 0630 h on 25 December the driller began lowering the reentry cone/casing assembly to the seafloor. Several QA/QC issues were identified during the making up of the casing and drilling assembly, including: (1) an improperly machined thread on a casing joint; (2) a ~0.020 inch under gauge 16 inch casing hanger which prevented connection to the Dril-Quip running tool until 3 h of grinding work enabled them to fit together; (3) one of the other 16 inch casing hangers was also found to be out of specification; and (4) the first set of HOC DTU950 underreamers failed to open and close properly during the predeployment test at the usual 30–35 strokes/min, requiring instead 80 strokes/min to open and a pressure in excess of 700 psi. This underreamer was set aside and another was picked-up; it performed normally.

Hole U1492D was started at 1620 h on 25 December at a tagged seafloor depth of 3666 mbsl, the same depth as for Hole U1492C. The drill-in casing method employed here used a mud motor to power rotation of the bit and underreamer bit assembly, which projects ~3 m below the bottom of the casing. The casing is 10.75 inch in diameter, the screened casing joints are 12.5 inch in diameter, and the underreamer arms were set to create a 14.75 inch diameter hole. Drilling proceeded smoothly until a harder layer was encountered at ~84 mbsf, a similar depth to a hard (but unrecovered) layer encountered while coring in Hole U1492C. The bit was was catching on this layer, causing the drill pipe to torque up and then detorque in the opposite direction when the bit was freed. On one such detorque, the pipe rotated enough to activate the casing running tool and release the reentry cone, and the reentry cone fell down the casing string and onto the seafloor over the hole. Shortly after this, at 0230 h on 26 December, the 211 m long casing string also disengaged from the casing running tool and dropped about 3 m. We could still drill ahead, and we were able to reengage the casing and penetrate to 93 mbsf. However, hole conditions remained poor and it was decided to pull the casing back to the ship and inspect the casing and drilling assemblies. On recovery, one cone was missing from the underreamer, but other parts of the assemblies were in working order. The casing string was hung off in the moonpool forward of well center.

Given the difficulties drilling into serpentinite mud containing rock clasts in this hole, we decided on a different approach. We decided to first drill the hole without coring to 225 mbsf using a 14.75 inch bit, then reenter this hole and drill in the casing using the mud motor and underreamer bit. At 1415 h on 27 December, Hole U1492D was reentered and reamed down to the previous total depth of 93 mbsf. From that point it took 17 h to advance the 14.75 inch bit to the target depth of 225 mbsf (11 m deeper than casing to provide an adequate amount of rathole). The drill bit was raised to 67 mbsf, then run back down to 225 mbsf, and the hole was swept three times with high-viscosity mud to clean out cuttings prior to pulling this bit out of the hole to prepare for our second attempt to install casing.

At 0930 h on 29 December, the rig crew moved the already-assembled casing string back to the center of the moonpool, reassembled the mud motor and underreamer, then lowered the casing and drilling assembly to the seafloor. Hole U1492D was reentered for the second time at 2300 h. The casing was lowered to 54 mbsf before taking weight, then drilling/washing with the underreamer continued slowly to 144 mbsf where the casing became stuck. Six hours were required to free the casing. After further slow progress was halted at 184 mbsf by poor hole conditions, the bit was pulled back to 96 mbsf to free the casing. We resumed drilling it in and we were able finally to drill all the way to the total target depth of 214 mbsf at an average rate of 10 m/h; the casing shoe was at 211 mbsf. The casing running tool was released at 2240 h. It was not possible to confirm that the latch ring on the casing hanger had fully engaged the reentry cone because clouds of cuttings and drilling mud obscured our camera images; however, this was not considered to be a significant problem for the installation. The drill string was raised back to the ship and was on the rig floor by 0915 h on 1 January.

Three tasks remained to make the cased hole ready for a future deployment of borehole monitoring equipment: clean the hole of any accumulated debris; install a bridge plug at its base; and install an ROV landing platform. A drilling BHA was lowered to the seafloor and reentered Hole U1492D to clean out any material that may have built up in the base of the casing. No obstructions were found down to 211 mbsf, and a 30 barrel high-viscosity mud sweep made sure the hole was clear. The BHA was raised back to the ship and the bottom part was exchanged to include the bridge plug deployment apparatus, and Hole U1492D was reentered. The bridge plug was to be set near the base of the casing to prevent formation muds from coming up into the casing. However, at 2300 h on 2 January, while the pipe was hung off at the rotary for a pipe connection, the drill string jolted, suggesting that the drill string had become attached to the casing. After completing the pipe connection it was confirmed that the mechanical bridge plug had set prematurely at a depth of 37 mbsf. After an unsuccessful attempt to unseat the bridge plug, the drill pipe was detached from it and the drill pipe was raised back to the ship, where the bridge plug release tool was inspected. Nothing was found to be wrong with the running tool. The prevailing theory is that during the pipe trip through the water column, the running tool setting ring rotated the 10 required turns. Then, after reentry, when the pipe was hung off on the elevator stool, the ship took a large heave and the slips on the bridge plug hung up in the gap between casing joints (opposite the coupling), which allowed the appropriate amount of force to be applied, causing the slips on the bridge plug to set. Since removal of the bridge plug required preparation time, we decided to move on to Site U1493 (proposed Site MAF-14A) at the foot of Big Blue Seamount, and return to Site U1492 later in the expedition. The drill string and positioning beacon were recovered and the 136 nmi sea passage to Site U1493 began by 1430 h on 3 January.

We arrived back at Hole 1492D at 2130 h on 19 January, after a 50 nmi, 5 h transit from Site U1497. Hole U1492D was reentered at 0740 h on 20 January with the purpose of hammering out the bridge plug. The bridge plug was tagged at 40 mbsf, and it was hammered using a custom-built tool over a period of 3 h before it gave way and moved downhole. The pipe was lowered and we relocated the bridge plug at 211 mbsf, just below the base of casing. The ROV landing platform was deployed by freefall, landing very close to centered in the reentry cone. The base of casing was cemented with five barrels of 14 ppg cement. Cementing became the expedition's preferred method of sealing the base of casing because of the risk of the mechanical bridge plugs setting prematurely. The casing at Site U1492D is ready for future deployment of borehole monitoring instruments. The ship departed at 0200 h on 21 January for the 144 nmi transit to Hole U1496C.

Principal Results

Cored sediments from all three holes consist of an uppermost unit of red-brown pelagic mud with lithic clasts, <4 m thick in Hole U1492A, overlying a lower unit of blue-gray serpentinite pebbly mud containing 5%–10% lithic clasts of serpentinized ultramafic rock. Hole U1492B has only a thin <23 cm thick upper layer of brown clayey pelagic mud, and it has a unit of green serpentinite mud with serpentinized ultramafic clasts immediately below the pelagic cover and a deeper unit of blue-gray serpentine mud. Hole U1492C has no upper layer of pelagic mud, rather it immediately encountered blue-gray serpentinite mud with serpentinized ultramafic clasts, indicating relatively recent mud eruption at this location.

The upper brown pelagic sediment units and the buff-colored uppermost portions of the serpentinite muds in Holes U1492A and U1492B are characteristically higher in natural gamma radiation than the serpentinite muds. Unlike Site U1491, there are no gravity-driven downslope deposits at Site U1492. The cores recovered at this location show the same sequence of predominantly serpentinite muds containing heavily serpentinized ultramafic clasts capped by a thin veneer of more oxidized, seawater-altered serpentinite muds and pelagic sediments. Ultramafic clasts in the deepest sections of the cores have the most extreme degrees of serpentinization; often they are soft enough to scrape with a fingernail. Conversely, ultramafic clasts in the brown to light green uppermost intervals retain hardness and frequently exhibit milder degrees of serpentinization.

Geochemical analysis of pore fluids at Site U1492 stabilizes at high pH values (≥10.6) below 10–20 mbsf at all three of the cored holes. The fluids are enriched in NH_3, Ca, and Sr, and are depleted in B, K, Li, Mg, Si, PO_4, Na, Cl, and Br relative to seawater. The composition of deep Site U1492 fluids is consistent with pore fluid data from gravity and push core samples from Yinazao (Blue Moon) Seamount (Hulme et al. 2010). The very low B and K in these fluids likely relate to little or no mobilization of these species from the shallow and cool (~13 km; 80°C: Hulme et al., 2010) décollement beneath Yinazao Seamount, as neither of these elements are abundant in the depleted upper mantle (e.g., Salters and Stracke, 2004; Savov et al 2005). The values are also consistent with experimental results documenting the retention and uptake of B and Li from fluids into sheet silicate phases at higher temperatures (~150°C; Seyfried et al., 1984). The high Ca and Sr has been suggested to result from the release of these elements from smectite as pressure and temperature increase (Hulme et al. 2010). However, the low inferred temperatures and the absence of B or K enrichments would appear to argue against such a model. Large enrichments in Ca (but not Sr) in porewaters from the inactive Torishima Forearc Seamount, and the common occurrence of rodingites in association with serpentinites (e.g., Shervais et al., 2006), indicate that Ca can be leached from peridotite, as even depleted harzburgite contains some Ca (Mottl et al., 2004). In the absence of high carbonate alkalinity, Ca and Sr can achieve high concentrations in solution.

Seventy-two whole-round microbiology samples were taken at Site U1492 and were immediately subdivided and processed according to the type of shorebased analysis: (i) Samples were fixed for total cell counts to quantify microbial biomass; (ii) Samples were stored at 5°C for multiple cultivation techniques (including FACS high-throughput media screening and detection of adaptation to physical parameters such as pressure tolerance); (iii) Samples were fast frozen at −80°C for molecular analyses, including small-subunit (SSU) ribosomal gene amplicon sequencing (to address community structure in detail), functional gene detection and quantification through quantitative polymerase chain reaction (qPCR), and single-cell genomics (to address individual cell contributions). In addition, metagenomics of the entire microbial community and metatranscriptomics of the most highly expressed genes will be used to establish metabolic potential as well as deeper ecological and evolutionary relationships. Finally, general samples were also preserved for the detection of viral counts and diversity.

The APCT-3 temperature shoe was the only downhole tool deployed at Site U1492. Seven formation temperature measurements were attempted; three yielded high quality data, two had medium quality data, and two gave low quality data which were not used. Two interpretations of the temperature data are possible. One is an upward fluid flow model that has a steep gradient close to the surface and a shallower gradient with depth, which reproduces the temperature estimates at all depths except for 51.7 mbsf, which is a low quality record. The alternative is a linear gradient of 12°C/km with a local temperature perturbation at 23.5 mbsf.

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